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ASPECTS OF PLANTING:
BIOLOGY AND PRACTICE

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ASPECTS OF PLANTING:
BIOLOGY AND PRACTICE

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TABLE OF CONTENTS

Page

OPENING REMARKS .... *A.J. Willcocks* i

Perspectives

INTRODUCTION .... *Dr. Keith M. McClain* ii

OPENING ADDRESS

1.0 FORESTATION: DEVELOPMENT OF THE PHYSIOLOGICAL CONNECTION .... *Dr. Roy F. Sutton* 1

1.2 Dawn of realization
1.3 Birth of the concept of RGC
1.4 Root growth capacity
1.5 Performance
1.6 Handling
1.7 New Zealand demonstration
1.8 The Dead Pine Gang
1.9 Summary
1.10 References

Appendix A - Forest Regeneration Surveys in Ontario 1918

Appendix B - Reasons for Slowness of Development of Institutional Concern in Ontario

Appendix C - Consequences of Stock Variability

Part 1 - BASIC SEEDLING PHYSIOLOGY

2.0 EFFECTS OF REFORESTATION PRACTICES UPON THE ENDOGENOUS GROWTH RHYTHMS OF TEMPERATE CONIFEROUS SEEDLINGS AND THEIR RESULTANT VIGOUR .... *Dr. Denis P. Lavender* 19

2.1 Introduction
2.2 Bud break
2.3 Shoot elongation
2.4 Dormancy
2.5 Root growth
2.6 References

Part 2 - SEEDLING PRODUCTION CONSIDERATIONS

BAREROOT AND CONTAINERS

Page

3.0 PRACTICAL ATTRIBUTES OF STOCK QUALITY ...... *Robert A. Klapprat* ...29

- 3.1 Introduction
- 3.2 Performance attributes

  - 3.2.1 Root growth potential
  - 3.2.2 Frost hardiness
  - 3.2.3 Stress resistance

- 3.3 Material attributes

  - 3.3.1 Bud dormancy

    - 3.3.1.1 Budbreak tests
    - 3.3.1.2 Dormancy release index
    - 3.3.1.3 Chilling sums
    - 3.3.1.4 Oscilloscope technique

  - 3.3.2 Dry-weight fraction
  - 3.3.3 Mitotic index
  - 3.3.4 Hormone analysis
  - 3.3.5 Electrical resistance
  - 3.3.6 Water relations
  - 3.3.7 Nutrient relations
  - 3.3.8 Food reserves

- 3.4 Seedling morphology

4.0 OBSERVATIONS ON THE REFORESTATION AND SEEDLING PRODUCTION FOR CROWN LANDS IN NEW BRUNSWICK .... *Niels H. Kreiberg* ...40

5.0 CURRENT PRODUCTION TECHNIQUES IN THE PRIVATE SECTOR .... *Susan Millson* ...46

- 5.1 Introduction
- 5.2 Bud development and lignification
- 5.3 Hardening

  - 5.3.1 Current crops
  - 5.3.2 Overwinter double crops
  - 5.3.3 Overwinter single crops

- 5.4 Conclusion

Part 3 - BASIC SEEDLING PHYSIOLOGY : HANDLING

Page

6.0 PHYSIOLOGICAL RAMIFICATIONS OF STRESS DURING HANDLING, STORAGE AND TRANSPORTATION OF SEEDLINGS .... *Dr. Dave R. DeYoe* 56

- 6.1 Introduction
- 6.2 Seedling stress - easy to miss
- 6.3 Is stress cumulative?
- 6.4 To the source - the cell
- 6.5 How does the cell respond to the environment?
  - 6.5.1 Seedling response to environmental signals
  - 6.5.2 The role of stress-sensitive regulators
- 6.6 What are the impacts of stress at the cellular level?
  - 6.6.1 Cell response to temperature extremes
  - 6.6.2 Cellular response to extremes in moisture status
  - 6.6.3 Cellular response to physical abuse
  - 6.6.4 Cellular response to light extremes
  - 6.6.5 Response to extremes in nutrition
- 6.7 Accountability
- 6.8 What can I do?

Part 4 - HANDLING: NURSERY TO THE PLANTING SITE

FROM COMPANY AND DISTRICT PERSPECTIVES

7.0 STOCK HANDLING BY DOMTAR .... *Wayne D. Young* ...82

- 7.1 Introduction
- 7.2 Stock handling - general
- 7.3 Stock handling - bareroot
- 7.4 Stock handling - container
- 7.5 Conclusions
- 7.6 Literature Cited

8.0 DISTRICT HANDLING PROCEDURES: SIOUX LOOKOUT................................ *Neale Waters* ...89

- 8.1 Introduction
- 8.2 Bareroot stock
- 8.3 Container stock
- 8.4 Conclusions

Page

9.0 DISTRICT HANDLING PROCEDURES: RED LAKE .... *Dan Pyke* ...94

9.1 Introduction
9.2 Bareroot handling

  9.2.1 Common handling techniques
  9.2.2 Differences between crown and FMA holder(s)

9.3 Container stock

  9.3.1 Common handling techniques
  9.3.2 Differences between crown and FMA holder(s)

9.4 Suggestions for improvement and limitation to implementation

  9.4.1 Bareroot - suggestions
  9.4.2 Limitations
  9.4.3 Container stock
  9.4.5 Limitations

9.5 Suggested research needs
9.6 Conclusions

Part 5 - ANOTHER ALTERNATIVE FOR REFORESTATION

10.0 AREA BASED PLANTING .... *Dave Lehane* ...100

11.0 SUMMARY REMARKS .... *Dr. Dave R. DeYoe* ...108

12.0 POST MEETING OBSERVATIONS .... *A.J. Willcocks* ...110

PART 6 - EVENING PRESENTATION - ABSTRACTS

SHOOT AND ROOT GROWTH RESPONSE OF BLACK SPRUCE CONTAINER STOCK SUBJECTED TO FIVE OVERWINTERING TREATMENTS .... *E.R. Frisby and R.J.Day* ...112

AN EXAMPLE OF NURSERY CULTURAL CONTROL OF SEEDLING FIELD PERFORMANCE .... *K.D. Odlum and S.J.Colombo* ...113

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K.M.M.

OPENING REMARKS

A.J. Willcocks, Manager
Northwestern Ontario Forest
Technology Development Unit

This workshop, entitled "Aspects of Planting: Biology and Practice" is the first sponsored by the Northwestern Ontario Forest Technology Development Unit. Being a new Technology Development Unit, this meeting is also our first attempt at large scale information transfer. It is certainly gratifying to see by the attendance that there is much interest in the subject matter that will be presented over the next couple of days. It is important that technological information get to those who through their work can make best use of it and that is why the content of this meeting is aimed at the many 150 forest technicians, company and ministry foresters and forest scientists that are here today.

Specifically, the objective of this workshop is to increase your awareness and knowledge of the impacts of seedling stock handling, both in the nursery and at the planting site, on field performance. This subject matter is most timely because most of you in attendance are just about to begin your spring planting program. Our program is also for the benefit of seedling growers. The anticipated interaction between the end users and the growers is expected to provide a worthwhile basis for continued dialogue. A special feature of this meeting is the evening opportunity to meet with our guest speakers: Drs. Roy Sutton, CFS, Sault Ste. Marie; Denis Lavender, University of British Columbia; and David DeYoe, MacMillan Bloedel, Nanaimo, B.C. I trust that each of us will have a learning experience over the course of this workshop and learn something from the workshop to allow us to improve the manner in which we handle stock in our own planting operations.

Before we proceed I would like to thank Dr. Keith McClain, OTIFBI, Thunder Bay for being the workshop moderator and for his efforts in program organization. I would also like to thank all our speakers who come from as far away as British Columbia and New Brunswick and speakers from our field Districts and companies who contributed time away from their busiest period of the year. Lastly, I wish to thank Nancy Knudsen who so efficiently organized the registration process.

Now, let's have a good workshop.

INTRODUCTION

Dr. Keith M. McClain, Symposium Moderator
Northern Forest Research Unit
OTIFBI, Thunder Bay

Whether most of us realize it or not, we have participants from at least three regions in Ontario, main office, and participants from Vancouver Island to New Brunswick. Such a diverse group is surely indicative of the interest in the subject matter that will be presented over the next few days. It also comes to mind that we in Ontario are at a very interesting point in forest management, and being with the Ministry for some time, I can say the route has been rather circuitous. Sometimes progress has been rapid and at other times, the progress has been rather slow. Nevertheless, Ontario's obvious commitment to regeneration has always been inherent in the organization and its people, but surprisingly, the means to achieve our goals were not always available.

With the advent of Forest Management Agreements, there was a dramatic increase in the numbers of people who were committed to regeneration. The new team approach now included not only Ministry staff, but also company foresters. The team approach has gone through growing pains, but is now functioning toward well defined objectives. Ultimate success in planning and achieving has, however, its foundations in the understanding of biology. I do not wish to ignore the wildlife component in the planning process in what I say, but I refer only to aspects of forest regeneration. Our actions must be guided by biological considerations if we are to expect acceptable results.

Who then specifically should have this understanding?
First, the planning team who must make decisions of what to plant, when to plant, and prepare post plant silviculture prescriptions.
Second, the producers of trees and these include our provincial nursery staff and the newest members of our team - the private growers. I wish to extend a special welcome to this group because in terms of trees produced on a provincial basis, they produce in excess of 90% of the container

stock that is planted in this Province. Having an understanding of seedling biology is critical to guide seedling production and allows for innovation; for example, production of site specific seedlings and application of specific growing regimes for hardiness development. Thirdly, a grasp of biology is necessary by those at the field level. The supervisor who lacks appreciation of the biological implications of certain field handling and planting practices, will fail to provide proper guidance to the planter with the ultimate result of poor performing plantations. The planter also requires an understanding of biology because he must make decisions every time before the shovel is placed into the ground such as, is this a good microsite? and/or what can be done to make a good microsite?

As we learned from Dave DeYoe in Kirkland Lake at last September's conference on Taking Stock (CFRC O-P-16) a tree is not just a stick with a green fringe. We all have something to gain by being here - take advantage of this opportunity - challenge the speakers - ask specific questions and above all, realize that each of us is a member of a **regeneration team** and that our efforts in our respective areas of responsibility must be guided by our knowledge of seedling biology. To help us in this regard we have assembled a distinguished group of individuals, scientists and forest land managers, who through the course of their presentations will provide us with basic biological information followed by descriptive practices. By the end of our meeting we should have a reasonably good sense as to what we are doing right and what practices we need to improve upon.

OPENING ADDRESS

1.0 FORESTATION: DEVELOPMENT OF THE PHYSIOLOGICAL CONNECTION

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1.1 INTRODUCTION

Institutional concern about the effectiveness of forestation efforts in Canada, generally, and in Ontario, specifically, has been sporadic (Appendices A and B).

1.2 **Dawn of realization** (P.C. Wakeley in the Southern states)

In some other jurisdictions, concern developed earlier than in Canada, thanks largely to a few individuals who were interested enough, to examine relationships between planting stock and field performance, and then to report their findings in mainstream journals. Philip Wakeley, a New Englander, was one of these individuals. He was 22 when he joined the United States Forest Service in 1924. The Southern pine planting program had begun just 5 years earlier, when the Great Southern Lumber Company planted about 8 ha (20 acres) of wildings in 1919-1920 at Bogalusa, Louisiana (Wakeley 1971). From 1924 to 1970, the area of planted stands in the 14 Southern pine states (from Maryland and Virginia south to Florida and west to Tennessee, Missouri, Oklahoma, and eastern Texas) increased from about 5,000 to 7,000,000 ha (13,000 to more than 17,000,000 ac).

When the oldest Southern pine plantation of any consequence was only 10 years old from seed, Wakeley was directed "to write an authoritative, definitive, and final technical bulletin on all phases of artificial reforestation in the Southern pine region". Whoever issued that directive had the wisdom to specify "all phases of artificial regeneration". For the Southern pine program, the connection between nursery stock production and field performance of outplants was made from the start. Wakeley's (1935) 115 page technical bulletin on "Artificial reforestation in the Southern pine region" was published in 1935.

Early in the Southern pine program, morphological grading worked well; the higher grades were consistently superior to the lower (Wakeley 1935). However, after the great expansion of the program that began in 1933-1934, and after new nurseries came into production, morphological grades became much less reliable (Wakeley 1949), although Wakeley always acknowledged that the grading of nursery stock according to morphological characteristics did much to keep survival rates from falling below tolerable levels (Wakeley 1971).

Studies by Wakeley from 1934 through 1941 (studies involving more than 122,000 trees) showed not only that **"some unidentified and uncontrolled influence frequently caused greater differences in initial survival than did drastic variations in planting technique"** (emphasis added), but also that morphological grading of Southern pines was not consistent in separating planting stock into that which could be relied on to perform well and that which could not.

In another study, one of a series begun in 1937-1938, Wakeley took seedlings of the same morphological grade from different nurseries and planted them together on several sites. Comparisons made in four states in four planting seasons may have suffered from uncontrolled differences in the handling experienced by the various stock lots, the importance of which was not suspected at the time, but the results confirmed Wakeley's view that "morphological grades were not consistently dependable guides to the selection of good seedlings" (Wakeley 1949).

As late as 1971, Wakeley, in connection with the Southern pines, wrote: "one great problem... remains unsolved. With a few notable exceptions here and there, especially perhaps in loblolly pine, initial survival of planted Southern pines has generally not been as good as might be wished **or as climate, sites, planting techniques, and protective measures would seem to warrant"** (emphasis added).

Poor correlation between grade and performance, a long series of observations, and intensive experimentation led Wakeley (1949, 1971) to conclude that the key to the problem lies in how the root system of an outplant reacts to its new environment during the first week or so after planting.

In Wakeley's words: "(1) The ability of southern pine seedlings to survive planting depends to a great extent upon their ability to extend existing roots and to initiate new ones within the first 10 days to 2 weeks after the seedlings have been planted; and (2) this capacity for prompt development of new root tissue depends less upon the size and morphological grade of the individual seedling than upon its internal chemical and physiological condition -- for convenience called 'physiological quality' " (Wakeley 1971).

1.3 Birth of the concept of RGC (E.C.Stone in California)

In California, for about 50 years until the mid-1950's, planting generally followed the precept that it should be done after growth of the planting stock has ceased in autumn and before growth begins again in spring (Schubert and Adams 1971). This meant that outplanting usually took place from the first week in October until it was halted by deep snow or frozen ground in late November or December; planting was resumed in the spring when the ground was free of snow, and continued until it was "too dry to plant".

Plantation failures were common, but accurate survival data were not available. The best estimate of survival rate among the more than 12 million seedlings planted in California in the 5-year period beginning in 1950 was "considerably below fifty percent" (Stone 1955). The cause of some of the failures (rodents, livestock, and competing vegetation) was clear, but other plantings failed for no apparent reason.

Unpublished reports by Dunning, Fowells, Kirk, and others at the USDA Forest Service's Pacific Southwest Forest and Range Experiment Station at Berkeley, California [on file at the experiment station, and cited by Schubert and Adams (1971)] show that, as early as the late 1930's, "poor physiological condition of the trees when they were field planted" was even then suspected of contributing to some of the high mortality rates suffered by seemingly good stock fall-planted into seemingly favorable soil and under suitable site conditions. Had these observations been documented and published in a recognized forestry journal, recognition of the importance of the physiological component of planting stock performance potential might have begun 10 or 20 years earlier than it did.

By 1955, however, concern about continued low rates of planting success brought E.C. Stone into the picture to look at possible seasonal variation in the physiological condition of nursery stock (Schubert and Adams 1971).

Stone (1955) carried out a study to ascertain whether or not physiological condition was a factor that resulted in low survival. Physiological condition of planting stock was judged (retroactively) on the basis of root development in a sub-sample after 60 days. Wakeley (1965) had reached the same conclusion from "a multitude of rather tenuous leads", i.e., that physiological quality exerts its influence on survival **primarily through the seedlings' ability to extend new root tissue into the soil of the planting site within a very few days after planting.**

Stone (1955) used five species, each represented by five samples of 10 seedlings. Fall-lifted stock was planted into 1-gallon (3.8 l) cans and moved into a greenhouse where favorable growth conditions were maintained. A pronounced difference in root development was evident at the end of the 60-day test period; in all species, some trees failed to produce roots. "Close examination of both seedlings that produced roots and those that failed to do so did not reveal any external morphological differences". The test trees were replanted for a further 120 days, by which time "almost all the seedlings which had not produced roots in the first 60 days were dead".

The small number of trees used, as well as the method of selecting stock from the nurseries, precluded any comparison of species, nurseries, or stock treatment. But this was the study that opened the door to the whole question of root growth capacity (RGC) [= root growth potential (RGP)] in forest tree planting stock. The development of the RGC concept has greatly advanced our appreciation of planting stock physiology.

1.4 Root growth capacity

It is now clear that root growth among trees of species commonly used in forest plantings can vary substantially with many factors, including season of the year, nursery climate (cf. Krugman and Stone 1966), nursery soil and its amendments, nursery watering regime, and the degree of mycorrhizal formation. The capacity of planting stock to grow new roots can also be influenced strongly by the time of lifting, the length and conditions of storage, and the planting environment into which the stock is placed. Fairly recently, handling has become recognized as a factor to be reckoned with (cf. Wakeley 1949, 1971; Stone 1955; Stone and Schubert 1959 a,b; Stone *et al*. 1962; Stone and Jenkinson 1970, 1971; and Tabbush 1986 a,b).

However, I'd like to make sure that we all understand what an RGC value is. A test of RGC is supposed to quantify the readiness of planting stock to produce new root growth after outplanting. Typically, a subsample of the planting stock of interest is placed under good growing conditions in a growth chamber, left there for a specified period, then examined for new root growth. Quite a variety of RGC test environments and test periods have been used by different workers, but in all cases, the new white roots (or some class of them, e.g., those 1 cm or more in length) are quantified in some way, and this value is reported as the RGC. It is important to keep in mind that this RGC value can vary greatly with even minor differences in the test environment, with the length of the test period, and with the basis chosen for quantifying the new root growth (Sutton 1987).

Quantification of this new root growth is not easy, and relationships between RGC and field performance are elusive and difficult to investigate (Sutton 1987): as I reported in my 1987 paper on RGC, "While, for plantation establishment, the importance of root growth in the establishment of outplants can be presumed..." (Burdett . 1983), and, while "a reasonable thesis seems to be that the greater the RGC... the greater will be the ability of such stock to survive and grow well" (Sutton 1980a), the relationship between the two has not been well documented (Sutton 1987).

Whether or not a useful relationship can be developed between RGC and field performance, the outlook for an outplant that has low or no RGC is bleak. Conversely, planting stock that has a very high RGC can be expected to perform well, at least up to the possibilities offered by the conditions it experiences at the site of outplanting.

1.5 Performance

Let's look, for a moment, at an **outplanting** operation in progress. Consider the tree that is being planted. How will the tree perform? What will determine its fate?

The **performance** of the tree depends in part on what the tree experiences from this point on. The **post-planting** influences of planting quality and site conditions can obviously influence the survival chances of an outplant, and just because an outplant does not die does not mean that it is home free; its growth can be affected for decades by some early post-planting experience, such as drought.

Planting quality has three main aspects: the adequacy of root/soil contact (Sutton 1978); the avoidance of excessive physical damage, e.g., breakage or crushing of twigs and/or stem and/or roots, abrasion of bark, and loss of buds; and the stability of the newly planted tree.

Some **site conditions** are of immediate importance to the new outplant: soil **moisture** sufficient to supply (in spite of imperfect root/soil contact) the moisture the tree needs if it is to maintain turgor, put out new root growth, and conserve its photosynthetic capability; **atmospheric relative humidity** will have considerable influence on the transpirational pull of water out of the outplant; the **temperature** of the root zone will influence the uptake of water by roots as well as the ability of roots to translocate it; the **temperature** of the foliage will also affect the water relations of the outplant; the **fertility** of the soil impinging on the roots strongly influences root development, especially root branching (Sutton 1980b); and, of course, pests of all kinds can inflict various kinds of damage either indirectly (as with weed competition for moisture) or directly (as with browsing).

These influences on the new outplant are important but fairly obvious -- provided someone takes the trouble to look. Controllable influences, such as planting quality, should be kept within specified limits by supervision. Site preparation is also controllable, although at the time of outplanting the degree to which it can be changed is rather limited. The planter, however, is usually presented with more than one kind of microsite into which an outplant can be introduced, and here also is a need and an opportunity for silvicultural input.

Up to this point, I have been talking about the post-outplanting factors that affect the performance of an outplant. But performance is also influenced by pre-outplanting factors such as nursery cultural regime, condition when lifted, duration and conditions of storage, and handling (up to and including planting) as well as by species and provenance.

In fact, the influence of an outplant's prior experience can be decisive, even when the tree is well planted in a favorable environment; this was dramatically illustrated by something I saw in British Columbia, at Red Rock Nursery in 1977: batches of lodgepole pine (*Pinus contorta* Dougl.) had been lifted the previous November, overwintered at -2° C, removed from storage on 3 May and shipped, although not before a sample from each batch had been taken and planted in the nursery. At that time, in all external characteristics, the batches were virtually indistinguishable one from another, and yet, when I saw the test plots in the nursery on 29 July, mortality was virtually total in some batches, and zero in others. One batch of planting stock, when planted by a given method in a given way on a given site, may flourish; another batch, identical in appearance, and treated identically, may perish.

Mortality of this kind most probably results from zero or very low RGC in the planting stock. The time of lifting can have a tremendous influence on the RGC of planting stock, especially in the pines (Pinus L. spp.) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco). Almost 30 years have passed since Lavender and Wright (1960) warned about the danger of premature lifting of Douglas-fir, and it is more than 10 years since Bunting (1977) found with red pine (*Pinus resinosa* Ait.) that success or failure could depend on a difference of only one or two weeks in the date of lifting. In jack pine (*Pinus banksiana* Lamb.), a difference of one week in fall lifting date was enough to make a 20-fold difference in field survival rate (Mullin and Parker 1976).

Many, perhaps most, of the remarkable differences in outplant performance between trees lifted at different times during the season, or lifted at the same time from different nurseries, may be explained on the basis of the dormancy process and physiological condition (Lavender and Cleary 1974). Premature interruption of the dormancy process is probably a major cause of the disappointing results that have so often attended early fall planting, especially of pines (Sutton 1982a).

Therefore, I would urge every nursery manager to take a sample (it need not be large but it should not be biased) from each major lot of stock as it leaves the nursery gate, and to plant it in the nursery. Equally, I would urge everyone who takes delivery of planting stock in the field to take a small representative sample of the stock on receipt and every few days thereafter, until all the stock has been outplanted, plant each sample in the least stressful situation available.

To be useful, these plots will, of course, need to be monitored. This extra work might be resisted, but the information obtained would be invaluable in pinpointing problems in handling. Such information is crucial to the development of a sound regeneration system.

Benzian and Freeman's (1970, 1974) work in the United Kingdom illustrates another effect that has often gone unrecognized. Benzian applied rather heavy top-dressings of nitrogenous fertilizer to nursery stock late in the growing season, without affecting the morphology of the stock, and thereby boosted the N concentration and content of the stock. The "unboosted" stock was good, high class stock; and though late-season application of nitrogen is often deplored on the grounds that it makes for succulence and increased susceptibility to frost and winterkill, Benzian found that it significantly improved the performance of Sitka spruce (Picea sitchensis [Bong.] Carr.) outplanted on harsh sites.

Nursery soil moisture conditions can influence the performance of planting stock after outplanting, through their effects on RGC (cf. Day *et al.* 1976) and stress resistance.

1.6 Handling

Plants do not like to be handled. Almost all plants and plant parts respond in some way to mechanical perturbation (Jaffe 1976, 1980, 1985, 1987; Biro and Jaffe 1984; Jaffe and Telewski 1984; and Takahashi and Jaffe 1984). I have seen a convincing instance of marked reduction of growth in nursery stock merely as a consequence of periodic remeasurement, even when this was done carefully.

The amount of handling needed by nursery stock prior to shipping decreases as the uniformity of the stock increases. Variability can be morphological or physiological, and variability of any kind is disadvantageous (Appendix C). Phases of handling include: lifting, bundling, packing, root trimming, nursery storage, distribution, on-site storage, and planting.

Tabbush (1986a,b), in the British Forestry Commission, studied the effect of rough handling on 1+1 Sitka spruce 15-20 cm tall. The trees were lifted in the fall and cool stored at 0-2° C until spring, when they were removed from storage and culled to reduce variability of stock for the study. Forty trees (not bundled) were sealed into each of four polyethylene bags. One bag served as a control, and the others were dropped from a height of 3 m onto a hard floor 1, 5, or 15 times. But for the dropping treatment, plants were handled with great care throughout. After treatment, 10 trees (selected at random) were tested for RGC using Burdett's (1979) method of rating. The remaining 30 plants per treatment were planted in the nursery, and their performance was assessed at the end of the growing season. No damage was visible to the naked eye in the root systems (nor, presumably, in the shoot systems) after the dropping treatment.

The results of this study by Tabbush clearly show the potential for reducing RGC and performance. The dropping treatment depressed not only RGC but also the rate of root growth. The rate of root growth seems to have been depressed by even one drop, and the increasing effect with increasing number of drops is clear. Survival after 1 year was significantly lowered by the most severe treatment.

Another study by Tabbush (1986b) in the same series showed that the amount of mycorrhizal development decreased with severity of handling in both Sitka spruce and Douglas-fir. Reduction in mycorrhizal development would be expected to contribute to water stress; Reid and Bowen (1979) have shown the importance of far-ranging "exploratory" hyphae in water uptake.

As Tabbush (1986b) pointed out, all operations from lifting through planting involve physical shock. The effect of successive shocks is likely to be cumulative.

1.7 New Zealand demonstration

Damage to planting stock during the period from lifting through outplanting is regarded in New Zealand as an integral part of the complex of problems of planting stock quality (Sutton 1980a). A particularly dramatic demonstration of the large effect that can result from differences in stock handling procedures was to be seen (and I'm sure is still to be seen) in New Zealand in a plantation of radiata pine (Pinus radiata D.Don) in Kaingaroa Forest. Although all were used in the same operational planting, some trees had been put through the conventional procedure of lifting, culling, sorting, grading, root trimming, tying, packing, and hand-planting from planting bags. Other trees had been lifted, placed in planting boxes (rigid, plastic-lined cardboard containers), and kept there until outplanted. The planting boxes were carried on the hip in a wire frame. Ironically, the purpose of the study had nothing to do with concern about handling effects. All that was intended here was a test of the acceptability to planting crews of the planting box compared with the conventional planting bag. No follow-up inspection had been scheduled, but the detrimental effect of handling on performance was so obvious that it proclaimed itself.

1.8 The Dead Pine Gang

In New Zealand forestry is practiced intensively. The main crop tree species, radiata pine, has phenomenal growth rates (e.g., Site Class 1 radiata pine: 40 m = 131 feet in 20 years). Consequently, responses to treatment are such that you can almost see them taking place. This may explain why the Dead Pine Gang (Figure 1; cf. Sutton 1980a) is of New Zealand origin. Is handling important? It certainly is!

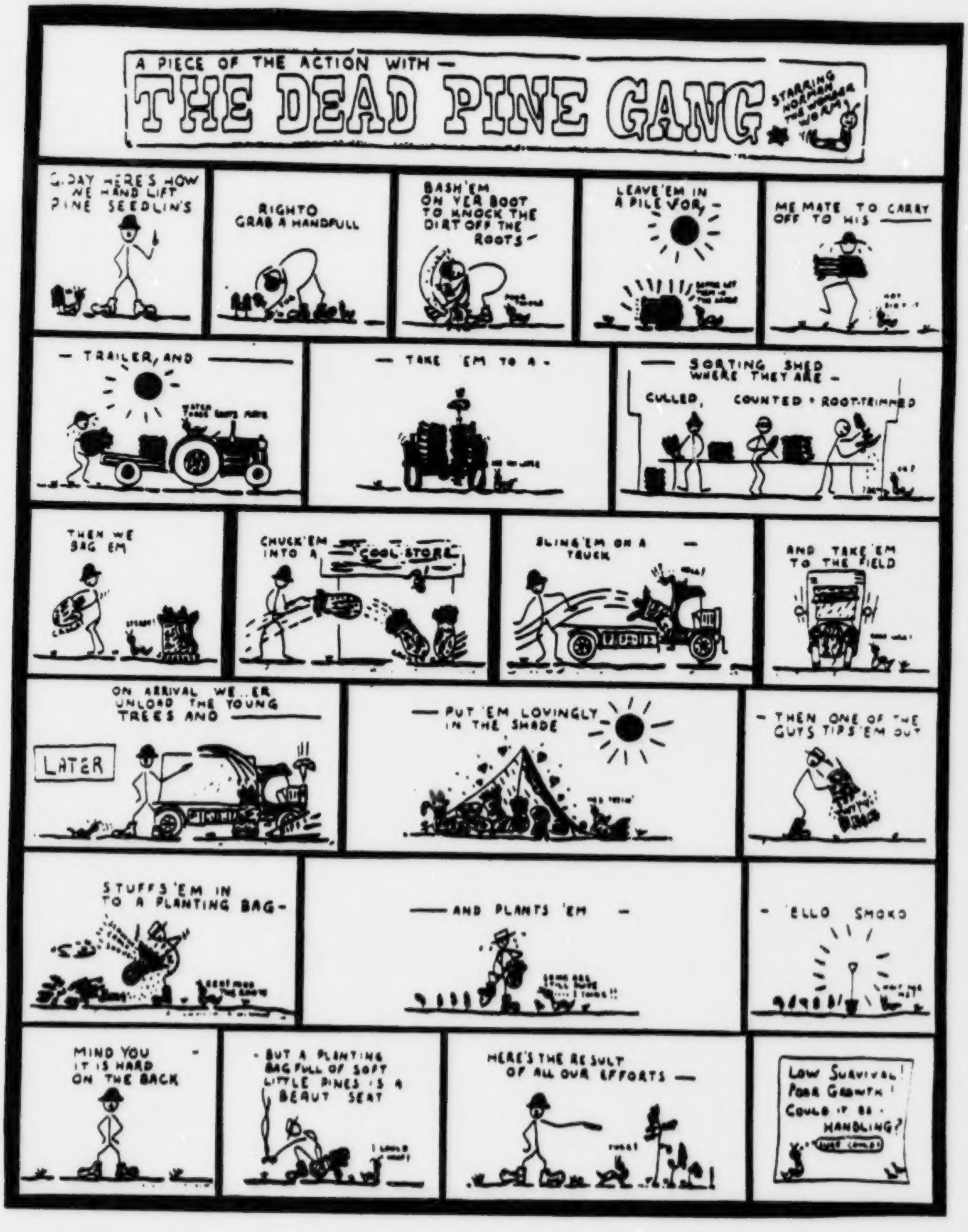
A PIECE OF THE ACTION WITH —
THE DEAD PINE GANG
STARRING NORMAN THE WONDER WORM
G'DAY HERE'S HOW WE HAND LIFT PINE SEEDLIN'S
RIGHTO GRAB A HANDFULL
BASH'EM ON YER BOOT TO KNOCK THE DIRT OFF THE ROOTS —
LEAVE'EM IN A PILE FOR —
ME MATE TO CARRY OFF TO HIS —
— TRAILER, AND —
— TAKE 'EM TO A —
— SORTING SHED WHERE THEY ARE —
CULLED, COUNTED + ROOT-TRIMMED
THEN WE BAG EM
CHUCK'EM INTO A — COOL STORE
SLING'EM ON A — TRUCK
AND TAKE'EM TO THE FIELD
ON ARRIVAL WE...ER UNLOAD THE YOUNG TREES AND —
LATER
— PUT 'EM LOVINGLY IN THE SHADE
— THEN ONE OF THE GUYS TIPS'EM OUT
STUFFS'EM IN TO A PLANTING BAG —
— AND PLANTS 'EM —
— 'ELLO SMOKO
MIND YOU — IT IS HARD ON THE BACK
— BUT A PLANTING BAG FULL OF SOFT LITTLE PINES IS A BEAUT SEAT
HERE'S THE RESULT OF ALL OUR EFFORTS —
LOW SURVIVAL! POOR GROWTH! COULD IT BE — HANDLING?

Figure 1. Stock handling by The Dead Horse Gang, as depicted by the New Zealand Forest Research Institute in 1979.

1.9 Summary

In summary, I would point out that the advances in forestation have come as a direct result of documented observation and publication of field performance.

The moral is self-evident. Perhaps 50 years have passed since the importance of the physiological condition of planting stock began to be suspected. The magnitude of some of the handling effects began to be more widely recognized about 10 years ago. We still have a considerable way to go before the whole of the RGC and mechanical perturbation story is unfolded. I can think of no one more qualified than our next speaker, Denis Lavender, to continue this unfolding.

1.10 REFERENCES

(Including those cited in the appendices)

Armson, K. A. 1976. Forest management in Ontario. Ont. Min. Nat. Resour., Toronto, Ont. 172 p.

Benzian, B. and Freeman, S. C. R. 1970. Nursery and forest extension experiments in tree nutrition. p. 168-170 In: Report on Forestry Research, 1970. For. Comm., London, England.

Benzian, B. and Freeman, S. C. R. 1974. Effect of late-season top-dressing of N (and K) applied to conifer transplants in the nursery on their survival and growth on British forest sites. Forestry 47:153-184.

Biro, R. and Jaffe, M. J. 1984. Thigmomorphogenesis: ethylene evolution and its role in the changes observed in mechanically perturbed bean plants. Physiol. Plantar. 62:289-296.

Bunting, W. R. 1977. Discussion. p. 86 In: R.F. Sutton, Ed. Plantation Establishment Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont., Symp. Proc. O-P-5.

Burdett, A. N. 1979. New methods for measuring root growth capacity: their value in assessing lodgepole pine stock quality. Can. J. For. Res. 9:63-67.

Burdett, A. N., Simpson, W. R., and Thompson, C. F. 1983. Root development and plantation establishment success. Plant Soil 71:103-110.

Canada 1966. National Forestry Conference, summaries and conclusions. Can. Dep. For., Ottawa, Ont. 46 p.

Crossley, D. I. 1968. Future requirements in reforestation and afforestation. Paper for Panel Discussion. Can. Inst. For., Annu. Meet., St. John's, Nfld. 11 p. (mimeo).

Day, R. J., Stupendick, J. T., and Butler, J. M. 1976. Root periodicity and root regeneration potential are keys to successful plantation establishment. Lakehead Univ., Sch. For., Thunder Bay, Ontario 17 p. (mimeo).

Hosie, R. C. 1953. Forest regeneration in Ontario. Univ. Toronto Press, Univ. Toronto For. Bull. No. 2, 134 p.

Jaffe, M. J. 1976. Thigmomorphogenesis: electrical resistance and mechanical correlates of the early events of growth retardation due to mechanical stimulation in beans. Z. Pflanzen. Physiol. 78:24-32.

Jaffe, M. J. 1980. Morphogenetic responses of plants to mechanical stimuli or stress. BioScience 30:239-243.

Jaffe, M. J. 1985. Wind and other mechanical effects in the development and behavior of plants, with special emphasis on the role of hormones. In: Encyclopedia of Plant Physiology, New Series Vol. 11, Springer-Verlag, Berlin.

Jaffe, M. J. 1987. Models of thigmomorphogenesis in plants. p. 139-143 In: D.W. Newman and K.G. Wilson, Ed., Models in Plant Physiology and Biochemistry. Vol. II. CRC Press, Boca Raton, Fla.

Jaffe, M. J. and Telewski, F. W. 1984. Thigmomorphogenesis: callose and ethylene in the hardening of mechanically stressed plants. p. 79-95 In: B.N. Timmerman, C. Steelink and F.A. Loewus, Ed.,Phytochemical Adaptations to Stress. Plenum Press, New York.

Kim, S. 1977. Analysis of young stage of plantation establishment. p. 109-110 In: R.F. Sutton, Ed., Plantation Establishment Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont., Symp. Proc. O-P-5.

Krugman, S. L. and Stone, E. C. 1966. The effect of cold nights on root-regenerating potential of ponderosa pine seedlings. For. Sci. 12:451-459.

Lavender, D. P. and Cleary, B. 1974. Coniferous seedling production techniques to improve seedling establishment. p. 177-180 in R.W. Tinus, W.I. Stein and W.E. Balmer, Ed., North American Containerized Forest Tree Seedling Symp. Proc., Great Plains Agric. Counc. Publ. 68.

Lavender, D. P. and Wright, E. 1960. Don't lift Douglas-fir seedlings too early because late lifting increases survival and vigor, studies show. Timberman 61:54-55.

Mullin, R. E. and Parker, J. D. 1976. Provisional guidelines for fall lifting for frozen overwinter storage of nursery stock. For. Chron. 52:22-25.

Ontario 1978. Proceedings of Ontario Conference on Forest Regeneration. Ont. Min. Nat. Resour., Toronto, Ont. 123 p.

Ontario 1979. Proceedings of The Second Ontario Conference on Forest Regeneration. Ont. Min. Nat. Resour., Toronto, Ont. 156 p.

Reid, C. P. P. and Bowen, G. D. 1979. Effect of water stress on phosphorus uptake by mycorrhizas in Pinus radiata. New Phytol. 83:103-107.

Schubert, G. H. and Adams, R. S. 1971. Reforestation Practices for Conifers in California. Calif. Resour. Agency, Dep. Conserv., Div. For., Sacramento, Calif., 359 p.

Stone, E. C. 1955. Poor survival and the physiological condition of planting stock. For. Sci. 1:90-94.

Stone, E. C. and Jenkinson, J. L. 1970. Influence of soil water on root growth capacity of ponderosa pine transplants. For. Sci. 16:230-239.

Stone, E. C. and Jenkinson, J. L. 1971. Physiological grading of ponderosa pine nursery stock. J. For. 69:31-33.

Stone, E. C., Jenkinson, J. L., and Krugman, S. L. 1962. Root-regenerating potential of Douglas-fir seedlings lifted at different times of the year. For. Sci. 8:288-297.

Stone. E. C. and Schubert, G. H. 1959a. The physiological condition of ponderosa pine (Pinus ponderosa Laws.) planting stock as it affects survival after cold storage. J. For. 57:837-841.

Stone, E. C. and Schubert, G. H. 1959b. Root regeneration by ponderosa pine seedlings lifted at different times of the year. For. Sci. 5:322-332.

Sutton, R. F. 1978. Root system development in young outplants, particularly white spruce. p. 172-185 In: E.E. Van Eerden and J.M. Kinghorn, Ed., Root Form of Planted Trees Symposium Proceedings. B.C. Min. For./Can. For. Serv., Victoria/Ottawa, Joint Rep. No. 8.

Sutton, R. F. 1979. Planting stock quality and grading. For. Ecol. Manage. 2:123-132.

Sutton, R. F. 1980a. Techniques for evaluating planting stock quality. Internatl. Union of For. Res. Org. (IUFRO) Workshop, New Zealand, August 1979. For. Chron. 56:118-120.

Sutton. R. F. 1980b. Root system morphogenesis. N.Z. J. For. Sci. 10:264-292.

Sutton, R. F. 1982a. Plantation establishment in the boreal forest: planting season extension. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont., Inf. Rep. O-X-344. 129 p.

Sutton, R. F. 1982b. Plantation establishment with bare-root stock: some critical factors. p. 304-331 In: G.D. Mroz and J.F. Berner, Comp. Artificial Regeneration of Conifers in the Upper Great Lakes Region 1982. Mich. Tech. Univ., Houghton.

Sutton, R. F. 1987. Root growth capacity and field performance of jack pine and black spruce in boreal stand establishment in Ontario. Can. J. For. Res. 17:794-804.

Tabbush, P. M. 1986a. Rough handling reduces the root growth potential and survival of barerooted conifer transplants. Quart. J. For. 80:185-188.

Tabbush, P. M. 1986b. Rough handling, soil temperature, and root development in outplanted Sitka spruce and Douglas-fir. Can. J. For. Res. 16:1385-1388.

Takahashi, H. and Jaffe, M. J. 1984. Thigmomorphogenesis: the relationship of mechanical perturbation to elicitor-like activity and ethylene production. Physiol. Plantar. 61:405-411.

Wakeley, P. C. 1935. Artificial reforestation in the Southern pine region. USDA For. Serv., Tech. Bull. 492, 115 p.

Wakeley, P. C. 1949. Physiological grades of Southern pine nursery stock. Proc. Soc. Am. For. 1948, Vol. 43:311-322.

Wakeley, P. C. 1954. Planting the Southern pines. USDA, Agric. Monogr. 18, 233 p.

Wakeley, P. C. 1965. The less obvious problems of nursery stock production. p. 77-92 In: Nursery Soil Improvement Sessions Proc., N.Y. State Univ. Coll. For. at Syracuse.

Wakeley, P. C. 1971. Lectures in forestry. Clemson Univ. Coll. For. Recreation Resour., Dep. For., Clemson, S.C. For. Res. Series No. 23. 40 p.

APPENDICES

APPENDIX A. FOREST REGENERATION SURVEYS IN ONTARIO 1918-.

Professor Hosie (1953) reviewed surveys of forest regeneration conducted in Ontario during the period 1918-1951. Hosie concluded that the results led to "confusion and disagreement regarding the nature [adequacy] of forest regeneration in different parts of the Province".

At the National Forestry Conference in 1966, the conclusion was drawn that "the extent of the regeneration problem was not clear nor was the cost calculated". Earlier national conferences (the first, chaired by Sir Wilfred Laurier, in 1906, the second in 1963) had even less to say about regeneration.

At the 1968 CIF Annual Meeting in St. John's, Newfoundland, Crossley (1968) wondered if it was not fair to say that professional foresters could be accused of hiding their heads in the sand on "the fundamental responsibility of regeneration". He called for an "almost complete reorientation in thinking by both Government and Industry and the marshalling of energy toward improved protection and the logistics of the completion of regeneration backlogs".

Armson (1976) noted deficiencies in the system of regeneration assessment and referred to the existence of "some confusion with respect to planting and regeneration assessments".

The first Ontario Conference on Forest Regeneration was held "to identify and discuss the factors which presently inhibit the expansion of the Ontario Regeneration Program in the boreal forest, and to recommend solutions so that we can significantly increase the annual area of regeneration" (Ontario 1978). At that conference, the truth began to surface institutionally, e.g., "no real effort to control seed quality", "two-thirds of our stock... has been stored under who-knows-what conditions, transported for a minimum of 24 hours and is flushed when we get it", "The type of stock is often unsuitable. 3+0 red pine has a root that cannot be put into a hole made by a shovel without first rolling it up".

At the follow-up conference in 1979, James Auld, the Minister of Natural Resources, proclaimed that he shared former Minister Frank Miller's enthusiasm for making forest regeneration the Ministry's top priority (Ontario 1979).

APPENDIX B. REASONS FOR SLOWNESS OF DEVELOPMENT OF INSTITUTIONAL CONCERN IN ONTARIO.

Several reasons can be advanced to account for the slow and unsure development of institutional concern:

1. Historically, wood supplies have been sufficient to allay concern about the continued availability of wood for the forest industry. The prospect of feeling the pinch of wood shortages did not emerge until the mid-1960s (Canada 1966).

2. While planting programs were small, sturdy transplant stock was generally used and labour was relatively cheap and plentiful. Spring-lifting and "hot" planting were the norm, and supervision was adequate. Success was common, and the causes of failures were usually obvious.

3. In other circumstances (e.g., with larger planting programs, or when less sturdy stock was used, or when stock had to be lifted and/or stored and/or planted at less propitious times, or when supervision was insufficient and/or ineffective), failure, though possibly common, may have been unsuspected (because follow-up inspections were not carried out) or unacknowledged (because of possible political embarrassment).

4. Where growth is slow, as in our boreal forest, and where the outcome of an outplanting operation often remains in doubt for several years afterwards, and especially if field foresters are relocated every few years, then the chances of sustained institutional interest, or even awareness, are small.

5. Improvements to the forestation effort were sought by changes, such as the introduction of new nursery stock classes and types, the effects of which were not evaluated scientifically either in preliminary trials or after general introduction. Furthermore, it is fair to say that,

because of the manner of their introduction, scientific evaluation would have been impossible.

APPENDIX C. CONSEQUENCES OF STOCK VARIABILITY

Apart from the difficulties associated with grading and culling of stock that is highly variable, certain undesirable consequences follow from excessive morphological variability among nursery stock within beds (Sutton 1982b). Variable stock is hard to characterize, and it is difficult or impossible to cater to efficiently in terms of planting site selection, site preparation, planting method, and so on. Problems arise as soon as variability exceeds rather limited bounds. The conventional response to morphological variability -- culling and grading -- is seldom applied rigorously, and the variation within supposedly graded stock is often large enough to raise doubts about the existence of cull standards (Kim 1977). If culling and grading are carried out, plants must be picked over and exposed to desiccation for a longer period than otherwise. To the extent that variation remains after culling and grading, the packaging system that is appropriate for the small stock will be inefficient and/or damaging to the large stock.

Root trimming is commonly done in an attempt to reduce morphological variability. Forcing larger than average stock into packages designed for average or smaller stock is of common occurrence.

Planting stock variability might also be physiological (Wakeley 1949, 1954; Stone 1955; Sutton 1979).

Undersized stock that escapes culling is sometimes outplanted (it is easy to plant) and sometimes not (because the runt won't grow anyway). In the first case, the small stock will face either an insufficiently prepared site, or one that has been over-prepared for larger stock. Oversized stock is often poorly planted, but if well planted, it might not need the degree of site preparation provided for the nominal grade.

PART 1

BASIC SEEDLING PHYSIOLOGY

2.0 EFFECTS OF REFORESTATION PRACTICES UPON THE ENDOGENOUS GROWTH RHYTHMS OF TEMPERATE CONIFEROUS SEEDLINGS AND THEIR RESULTANT VIGOUR

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2.1 INTRODUCTION

Unlike animals, who can either move or fashion shelter against unfavorable weather, plants are prisoners of their environment. They have evolved, therefore definite annual cycles which permit on the one hand the active growth evident in spring and summer months, and on the other hand, the development of resistant configurations which can withstand extremes of drought and temperature. The morphological sequence inherent in a typical annual life cycle, i.e. bud break, shoot elongation, dormancy, are relatively easy to recognize and are collectively termed the "phenology" of a plant. Underlying these changes, however, are complex shifts in the biochemistry which are but poorly understood. The importance of the changes in the biochemistry of physiology of tree seedlings which are induced by the changing seasons was first recognized by Wakeley (1948), who discussed the effects of physiological grades of pine seedlings in plantation survival and growth. Unfortunately, although a significant literature has since developed concerned with seedling physiological changes throughout the year, our understanding of the basic causes which give rise to wide differences in seedling growth and survival is still minimal. This paper will review the annual cycle of the shoots and roots of coniferous seedlings, largely utilizing examples of species native to western North America because other members of this symposium are far more conversant with Ontario species than I, and the effects of reforestation practices upon subsequent seedling vigour.

2.2 Bud break

Of all the events in the annual growth cycle of coniferous seedlings, the one most readily recognized and defined is bud break. In some respects, it is unfortunate that this is true because scientists concerned with factors affecting bud break have been inclined to treat it as a point event instead of merely one brief stage in shoot elongation (Lavender, 1988). The consensus of workers concerned with environmental factors related to bud break is that this event is controlled almost exclusively by temperature (Lavender, 1981). However, attempts to predict the timing of bud break through the use of a technique termed "heat sums" have met with only limited success at least partially because of an inability of the investigators to separate effects of chilling temperatures in releasing dormancy and the role of these same temperatures in satisfying the heat requirements of shoot elongation. Research has shown that the heat requirements for shoot elongation are strongly controlled by the genetic makeup of the individual tree, i.e. if tree A breaks its buds before tree B in 1988, it will in 1989, 90, etc., even though spring temperatures may differ widely during these years. Research has also shown that coniferous seedlings have a low resistance to stress during bud break.

2.3 Shoot elongation

Shoot elongation is really a continuation of the growth process which initiated with the resumption of cell division and elongation prior to bud break. With many temperate conifers the period of shoot elongation is very conservative with respect to the period of favourable weather as it frequently begins well after the last killing frost and terminates long before the onset of freezing weather in the fall. In essence it represents, for determinate plants such as the spruces, many pines, firs and Douglas-fir, merely the time required to expand the initials laid down during the previous growing season. Other species, such as the cedars, have a much more flexible growth period wherein newly formed initials are continuously produced and expanded during favourable weather. However, in the case of germinants and one to three year old seedlings even the determinate species cited above have an indeterminate growth habit to some extent and are affected, therefore, by the environment to a much greater extent than are the mature trees. This difference may appear to be academic, but in actuality it is of extreme importance in nursery management as the following discussion will demonstrate.

2.4 Dormancy

A typical coniferous seedling in the north temperate zone will initiate growth when the seed germinates in the spring. The active elongation of the shoot will continue until mid-summer, when it will gradually develop the first phase of dormancy commonly termed "quiescence". The environmental parameter stimulating "quiescence" differs with species. There is evidence in the case of Douglas-fir and possibly lodgepole pine that the summer drought common to western North America is the prime cause. In the case of boreal species such as white spruce, the gradually shortening days of mid-to-late summer are associated with the initiation of dormancy. Whatever the factor, it is important to note that the nurseryman, particularly the nurseryman who cultivates his coniferous crop in a greenhouse, has sufficient control over the seedling environment that he can dramatically affect the length of the period of active growth and the timing of the initiation of dormancy. If the nurseryman elects to postpone the initiation of dormancy of his seedlings, perhaps to achieve greater size, he should recognize that he runs the risk of disrupting the synchrony of the seedling physiology with the environment external to the nursery. And there has been significant research (Lavender, 1981, 1988) which demonstrates that such disruption can persist throughout the dormant period and result in delayed and weak resumption of growth the following spring.

Trials with white spruce seedlings which have initiated dormancy in June of their second growing season and which are then "hot planted" in British Columbia in July and August, suggest that the seedling resistance to the stress inherent in the reforestation process is at least moderate during this period. But such trials have also demonstrated that the mere cessation of seedling shoot elongation is not tantamount to frost hardiness as, in areas wherein summer frosts are common, the summer planted seedlings have been frequently damaged by frost.

If the nurseryman does not stimulate continued shoot elongation by the use of irrigation or extended photoperiod, the quiescent phase of dormancy will gradually change until, by early fall, the seedling is in a period of dormancy commonly termed "rest". By definition, "rest" is that phase of the dormant period when the seedling will not grow even if it is exposed to an environment which, during spring or early summer, would be considered optimum for active growth. In contrast, "quiescence" is triggered by environmental factors unfavourable to growth and, if the environment is modified to favour growth, the seedling will resume shoot elongation. When such changes occur in nature, the shoot growth that is produced is termed "lammas" growth (Rudolph, 1964).

During "rest" which may, depending upon the species, extend from early summer until late fall, seedlings have relatively low resistance to stress and are particularly sensitive to conditions inherent in cold storage (Lavender & Wareing, 1972). And the nurseryman should recognize that seedlings have evolved with a requirement for the weather sequence which commonly occurs in fall during rest. If seedlings are grown for an extended period during summer, there will not be sufficient time for the necessary changes in physiology to occur prior to the onset of cold winter conditions. As a result, the plant's physiology will be out-of-phase during the winter and result in the aforementioned weak growth response in spring.

If the seedlings are in phase with their environment, the rest phase of dormancy will be gradually broken by exposure of the plants to temperatures of about 5°C. This requirement for low temperature treatment differs with plant species. Nienstaedt (1967) showed that white spruce seedlings require 4 to 8 weeks, whereas Lavender (1986) showed that Douglas-fir requires 13 to 15 weeks. The measure of the effect of chilling temperatures upon the release of rest is commonly the response of seedlings to favorable growth conditions. With increasing exposure to low temperatures, seedlings are increasingly able to initiate shoot growth until the number of days from the beginning of a favorable growth environment subsequent to chilling until bud break is minimal. At this time, the chilling requirement is said to be satisfied. At this time, too, seedling resistance to stress is maximum, so the period between the end of rest and the initiation of growth in the spring is the optimum time to conduct the procedures necessary for reforestation. In climates which prohibit reforestation activity in winter, the period immediately after the end of rest is the optimum time to initiate cold storage of seedlings.

With reference to the above, it is interesting to note that predictions of probable future climate change universally indicate a substantial warming trend, particularly during the winter. For many horticultural species and forest trees such as Douglas-fir, such warming could well result in winters whose temperatures were too high to satisfy the "chilling" requirements of the species (Lavender *et al*, 1986). In all probability such an effect will not occur with boreal species such as white or black spruce because it will require a much greater than predicted warming to significantly affect the period of time in which temperatures of about 5°C may be expected in their current range and because the chilling requirements of these species are relatively short. Nonetheless, this negative aspect of climate change is one which should concern scientists planning for the future of our forest stands.

The preceding discussion of the phases of dormancy has been based upon the classical botanical definition of dormancy, i.e. "any case in which a tissue predisposed to elongate (or grow in some other manner) does not do so" (Doorenbos, 1953). Such definition of dormancy may be of interest from a botanical standpoint, although it has the weakness that it does not describe basic physiology, but it does not address the needs of forest nurserymen. A second definition of dormancy is based upon the stress resistance of the plant. According to this definition, deep dormancy occurs, not during the period of rest when the plant will not respond with a growth response under a favorable environment, but the quiescent period following rest when the plant is very resistant to stress. Figure 1 presents a graphical representation of dormancy according to each of these definitions - it may be seen that the curve which represents the classical definition generally precedes that derived from measurements of stress resistance. It should be noted, too, that, unless the changes in physiology reflected by the curve for the classical definition do not proceed normally, the curve representing stress resistance will be much lower.

The foregoing discussion has demonstrated that: 1) coniferous seedlings have a definite annual growth cycle; 2) associated with the growth cycle are underlying changes in seedling physiology which are but incompletely understood; 3) subsequent seedling vigour may be strongly affected by cultural practices which modify either (1) or (2). Examples of the sensitivity of seedlings to variations in nursery practice include:

1) recent trials with lodgepole pine and white spruce seedlings which were exposed to either nine or sixteen hour photoperiods during the month of August. Overwinter

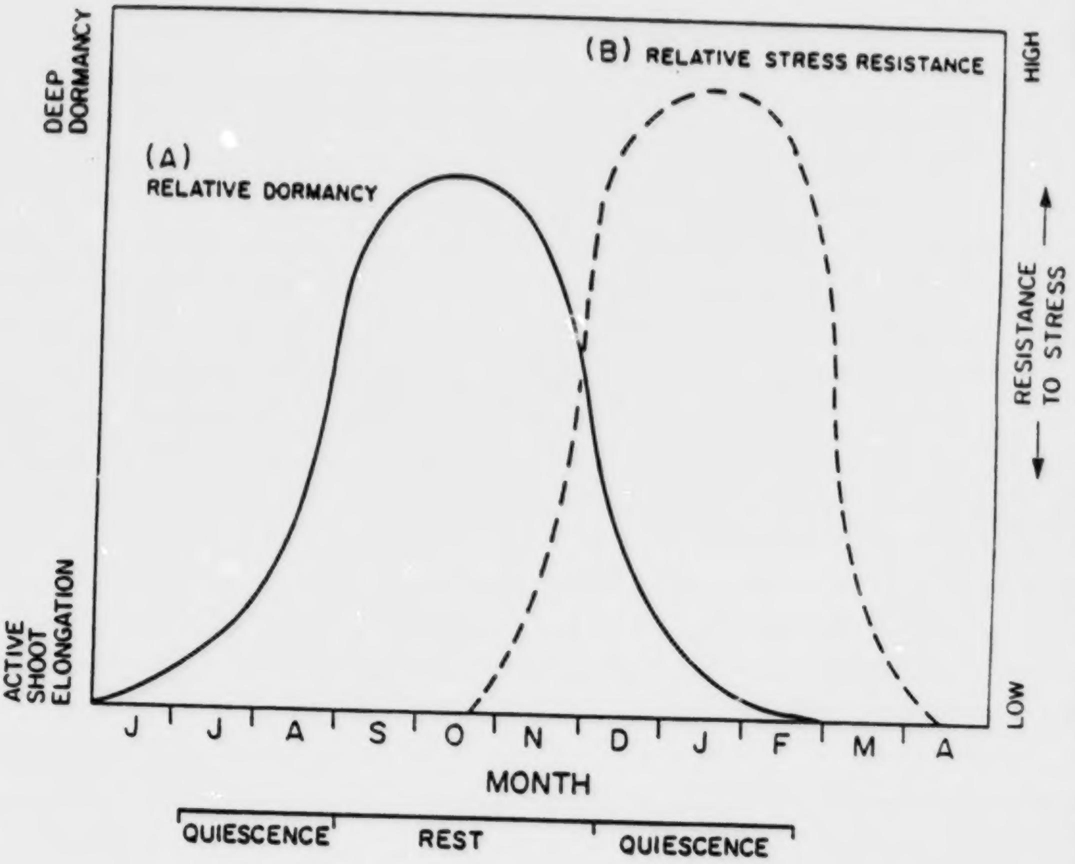

Figure 1. Relationship between classical dormancy (A) and dormancy as defined by stress resistance ("hardening off") (B) in Douglas-fir. The curve defining stress resistance is based on data for the period early October - early March. Very probably increased resistance to drought stress parallels development of quiescence in midsummer. But I know of not data which quantify this relationship.

survival of the plants exposed to the short photoperiod was one hundred per cent, whereas that of seedlings of both species exposed to the long photoperiod was much less; for the pine, less than ten per cent, and

2) Douglas-fir seedlings exposed to sixteen hour photoperiods in September but otherwise grown under natural conditions broke their buds three weeks later the following spring than did similar seedlings which received natural photoperiods for the same period.

It is not clear whether the differences in survival in the first example above were due to a disruption in the biochemical sequence associated with dormancy or whether the long photoperiod treatment prevented development of cold hardiness, a parallel but separate phenomenon.

As noted earlier, "hot" lifted white spruce seedlings in mid-summer are quiescent, but lack frost resistance. This is because such plants have not experienced the following sequence of environments, shown by Weiser (1970) to be necessary for maximum development of cold hardiness, i.e. a) short days, mild temperatures; b) short days, temperatures near 0°C; c) shorts days, temperatures well below 0°C. Other investigators (Mexal *et al*. 1979) have suggested that a period of short days, i.e. eight hours of light per day, may substitute for low temperatures. However, their populations were not subjected to extreme temperatures and, hence, their data are not, perhaps, contradictory to that of Weiser. More recently, Colombo (1985) has shown that a prolonged short day treatment of black spruce seedlings held in greenhouses can improve cold hardiness significantly over that obtained by seedlings placed under natural conditions in late summer. The nurseryman should recognize that the first requirement for development of cold hardiness is stored photosynthate; the second, cessation of shoot elongation and development of at least quiescence. Nursery culture, then, which limits photosynthesis by crowding seedlings or which prolongs active shoot growth beyond mid-summer will affect development of cold hardiness adversely.

2.5 Root growth

Because the seedling shoot is a stronger "sink" for carbohydrates that the roots, root growth of most perennial temperate zone plants is largely restricted to the period of the year when the shoots are inactive. Further, roots will not elongate into dry soils so in areas such as western North America, which has a distinct drought period in summer, root growth is further restricted. Lyr & Hoffman (1967) suggest that, as a result of these constraints, root growth of perennial temperate zone plants peaks in late winter, when the soils are not frozen but when air temperatures limit shoot growth, and again in the fall when soils are moist but not yet frozen.

A series of studies (Lavender & Hermann, 1970; Lavender, unpublished; Zaerr & Lavender, 1974) has shown for Douglas-fir that root growth is independent of the physiological state of the bud, reflects primarily the root and not the shoot environment, and is absolutely dependent upon some substance in addition to carbohydrate exported from the foliage. The lack of dependence of roots for material exported from buds shown in these studies probably explains the inability of other workers to demonstrate correlations between the state of dormancy of the seedling buds and the growth potential of roots.

It is often argued that if seedlings are to survive after outplanting they must demonstrate vigorous root growth to explore adjacent soil for supplies of nutrients and moisture. Accordingly, a parameter, root growth potential, has long been suggested as a measure of a seedling's potential for survival (Stone *et al*. 1962). More recently, a number of workers have published data which demonstrate varying degrees of correlation between seedling root growth potential and seedling survival (Ebell, 1988; Ritchie, 1985; Sutton, 1983). However, the root growth of coniferous seedlings is relatively limited, even under the most optimal environments. Burdett *et al*.(1983) for example, suggest a scale running from no root growth after one week of culture in a favorable environment for poor seedlings to about thirty centimeters for very good seedlings. When compared with the root growth of rye seedlings, which can produce a kilometre of new roots in a day, the growth of even very good seedlings of conifers is, at best, modest. Actually, it is probable that the significance of root growth potential is that it is a measure of seedling vigour. Certainly, seedlings of low vigour produce few roots but it is the lack of vigour rather than an inability to explore significantly greater volumes of adjacent soil and hence access greater supplies of moisture and nutrients, which is the probable reason for their low survival potential. Data supporting this interpretation were reported recently (Baker-Katz *et al*, 1988). In this study Douglas-fir seedlings, planted on an extremely droughty slope with intense interspecific competition from canyon live oak, survived for five years with virtually no root extension from the original root mass.

2.6 REFERENCES

Baker-Katz, K., S.D. Tesch and S.D. Hobbs. 1988. Five-year effects of greenleaf manzanita and canyon live oak competition of Douglas-fir survival and growth. Abstr. #4 in Northwest Science 62 (2), p.65.

Burdett, A.N., D.G. Simpson and C.F. Thompson. 1983. Root development and plantation establishment success. Plant and Soil 71:103-110.

Colombo, S.J. 1985. Improving the quality of overwintered container stock using extended greenhouse culture. In: Proceedings Nurserymen's Meeting Swastika Forest Station June 18-21, 1984. Ontario Ministry of Natural Resources, Toronto, Ontario. p. 28-35.

Doorenbos, J. 1953. Review of the literature on dormancy in buds of woody plants. Medelingen van de Landbouwhogeschool te Wageningen/Nederland 53:1-24.

Ebell, L.F. 1988. Information package for alternative root growth capacity testing systems. F.S. 189(1)INF 82/6. Ministry of Forests and Lands, Province of British Columbia, Victoria.

Lavender, D.P. 1988. Dormancy. In: Techniques and approaches in forest tree ecophysiology. J.P. Lassoie & T.M. Hinckley, Eds. CRC Press, Boca Raton, Florida (In press).

Lavender, D.P. 1981. Environment and shoot growth of woody plants. Research paper 45, forest Research Laboratory, School of Forestry, Oregon State University, 47p.

Lavender, D.P., R.K. Hermann and D.D. McCreary. 1986. Chilling requirement of douglas-fir. In: Proceedings of the Ninth North American Forest Biology Workshop. C.G. Tauer and T.C. Hennessey, Eds. Oklahoma State University, Stillwater, Oklahoma. P. 85-93

Lavender, D.P. & P.F. Wareing. 1972. Effects of daylength and chilling on the responses of Douglas-fir (Pseudotsuga Menziesii (Mirb.) Franco) seedlings to root damage and storage. New Phytologist 71:1055-1067.

Lavender, D.P. & R.K. Hermann. 1970. Regulation of the growth potential of Douglas-fir seedlings during dormancy. New Phytologist 69:675-694.

Lyr, H. and G. Hoffman, 1967. Growth rate and growth periodicity in tree roots. International Review of Forest Research 2:181-236.

Mexal, J.G., R. Timmis and W.G. Morris. 1979. Cold hardiness of containerized loblolly pine seedlings, its effect on field survival and growth. Southern Journal of Applied Forestry. 3:15-18.

Nienstaedt, H. 1967. Chilling requirements in seven Picea species. Silvae Genetica 16:65-68.

Ritchie, G.A. 1985. Root growth potential: principles, procedures and predictive ability. In: Proceedings: Evaluating Seedling Quality: Principles, Procedures, and Predictive Abilities of Major Tests. M.L. Duryea, Ed. Research Laboratory, Oregon State University;, Corvallis, Oregon, p. 93-105.

Rudolph, T.D. 1964. Lammas growth and prolepsis in jack pine in the lake states. Forest Science Monograph 6. 69 p.

Stone, E.C., J.L. Jenkinson and S.L. Krugman. 1962. Root-regeneration potential of Douglas-fir seedlings lifted at different times of the year. Forest Science 8:288-297.

Sutton, R.F. 1983. Root growth capacity: relationship with field root growth and performance in outplanted jack pine and black spruce. Plant and Soil 71:11-122.

Wakeley, P.C. 1948. Physiological grades of southern pine nursery stock. Proceedings of the Society of American Foresters 43:311-322.

Weiser, C.J. 1970. Cold resistance and injury to woody plants. Science 169:1269-1278.

Zaerr, J.B. and D.P. Lavender, 1974. The effects of certain cultural and environmental treatments upon the growth of roots of Douglas-fir (Pseudotsuga menziesii (Mirb) Franco) seedlings) In: II. International Symposium Ecology and Physiology of Root Growth. G. Hoffman, eds. Akademie-Verlag, Berlin. p.27-32.

SEEDLING PRODUCTION CONSIDERATIONS

BAREROOT and CONTAINERS

3.0 PRACTICAL ATTRIBUTES OF STOCK QUALITY

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3.1 INTRODUCTION

The characteristics of planting stock which reflect quality can be characterized by performance attributes and material attributes (Ritchie, 1984). Seedling performance attributes are usually assessed by subjecting plants to various environmental regimes while material attributes are assessed by direct measurement of morphological features. Throughout the production stages at the nursery, steps are taken to ensure "stock quality". What follows is simply a review of a paper presented by Dr. Gary Ritchie at the Bareroot Nursery Technology Workshop held at Oregon State University, Corvallis Oregon, 1982. The proceedings of this workshop have been published (refer to Duryea and Landis, 1984). Also included is information from the Cultural Guidelines and Procedures at the Thunder Bay Nursery.

3.2 Performance attributes

3.2.1 Root growth potential

A key to survival and establishment is rapid resumption of water and mineral uptake after outplanting. This uptake depends upon the ability of the seedling to regenerate new roots. This ability is called root growth potential. A high root growth potential is often correlated with high field survival. A standard method to estimate root growth potential is to pot the seedlings in a light soil and hold under conditions favorable for root growth for a specific period (28 days). After this time seedlings are carefully washed out of the pots and new roots are counted and measured.

Some disadvantages of this method include:

1. it requires substantial quantities of potting soil and greenhouse space.
2. measurements and counting are laborious and time consuming.
3. results are not available for 1 month.

Shortcuts which have been used to estimate root growth potential have been tried and include the following:

- hydroponic growing
- shortening testing time
- streamlining measurement procedure.

3.2.2 Frost hardiness

The level of frost hardiness is the minimum temperature at which a certain percentage of a randomly selected seedling population will survive or sustain a given level of damage.
Frost hardiness increases rapidly in response to changing photoperiod, low temperatures, and other factors.

The mechanisms of frost hardiness are very complex and involve many interacting factors including:

1) ability of the plant tissue to
    a) avoid or tolerate freeze desiccation
    b) prevent lethal intracellular ice crystal formation
    c) withstand non lethal extra cellular ice crystal formation.
2) the propensity of cell water to reach subfreezing temperatures without freezing.

Two approaches are normally followed in assessing frost hardiness:

1) subjecting plant material to subfreezing temperatures.
2) evaluating the effect of this treatment.

The steps in subjecting plant samples to freezing temperatures are:

1) randomly select a sample of seedlings from the population of interest.
2) place them into a freeze chamber.
3) lower temperature at given rate to desired level.
4) hold the test temperature for a given period.
5) return at a given rate to start temperature.

Evaluating frost damage by visual inspection after several weeks in a greenhouse or growth chamber is the evaluation method with most certainty. The disadvantage of this approach is the time and space required. Hence, other techniques can be considered which include:

- impedance ratio measurement and
- diffusate conductivity method.

3.2.3 Stress resistance

A technique has been developed for assessing a seedling's overall "physiological soundness". This involves subjecting half of a randomly selected lot of trees and suspending them in a growth cabinet for 15 minutes at 30% RH and 32°C. Then after soaking their roots for 5 minutes they are potted and placed alongside the other half of the lot which was potted as a control. The seedlings are then periodically evaluated. Generally, lots in the poorest condition will show damage symptoms earliest. A decision would have to be made so that "poor" lots are not planted at all and "fair" lots planted only in areas where severely stressful conditions will be absent.

3.3 Material attributes

3.3.1 Bud dormancy

Perennial plants such as trees can adapt to a wide range of environmental conditions by reacting to cues such as photoperiod and soil temperature. These plants will cycle through various physiological states to become tuned to ambient conditions. This is called the dormancy cycle (Figure 1). Besides knowing when seedlings enter true dormancy, we must also know the intensity of dormancy at any time. Some methods of measuring the intensity of dormancy include the following:

3.3.1.1 Budbreak tests

The main steps in determining the rate of bud burst are: 1) select samples, 2) pot up, 3) place in a suitable environment, 4) observe daily the progression of bud development, 5) record date of bud break, and 6) average the results. The dormancy intensity weakens as winter chilling accumulates; therefore, buds will break faster the later in the winter.

3.3.1.2 Dormancy release index

The relationship between "days to bud break" and "chilling sum" can be fitted with a reciprocal function. Extrapolation of this function or dormancy release index may provide an estimate of the earliest date to begin lifting for storage (Figure 2).

3.3.1.3 Chilling sums

This is determined simply by monitoring air temperature at about 1

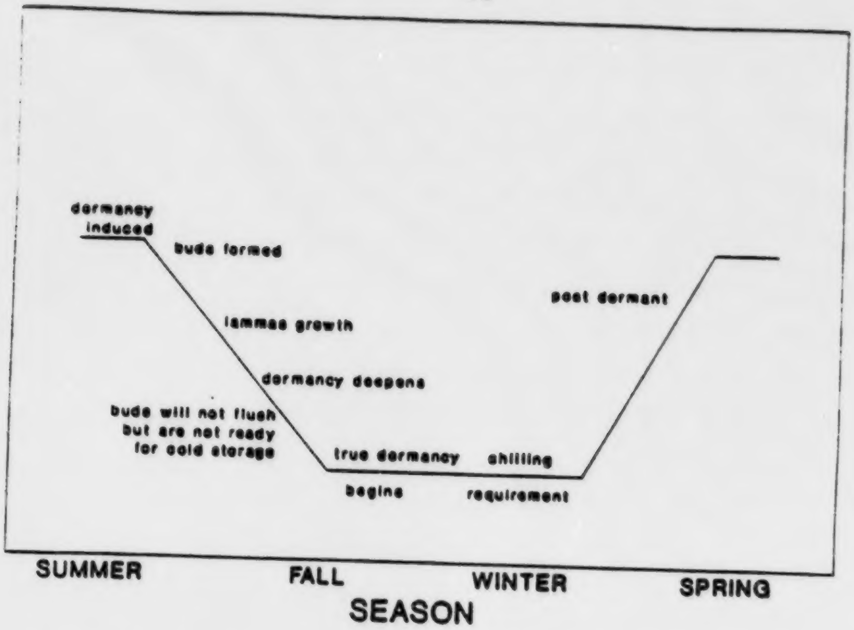
dormancy induced
buds formed
lammas growth
dormancy deepens
buds will not flush but are not ready for cold storage
true dormancy begins
chilling requirement
post dormant
SUMMER
FALL
WINTER
SPRING
SEASON

Figure 1. Generalized dormancy cycle depicting the progression of seedling physiology from early summer to early spring the following year.

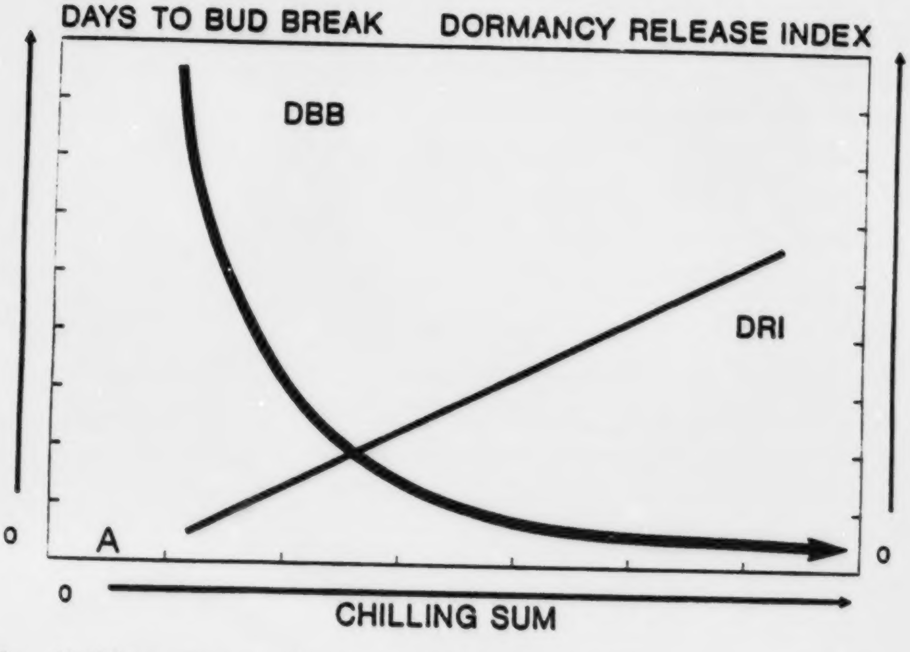

Figure 2. Chilling sum at time of lifting is related to terminal budbreak (DBB) under standard test conditions. Resulting values can be expressed as a dormancy release index (DRI). Extrapolation of DRI (straight line) to a point on the X-axis may provide an estimate of the earliest date to begin lifting for storage (after Ritchie 1984).

meter above the ground and summing the hours during which the temperature is within some range known to be effective at releasing dormancy in the species of interest.

3.3.1.4 Oscilloscope technique

Square wave electrical signals are produced differently in plant tissues. Such differences can be related to periods of plant activity and inactivity. Unfortunately the electrical signals are affected by other factors such as touching or moving samples making this method quite unreliable.

3.3.2 Dry-weight fraction

The dry weight fraction of seedlings changes annually in a predictable manner and reflects the seedling physiological condition and therefore can be used as an indirect measure of seedling dormancy.

$$\text{dry weight fraction} = \frac{\text{oven dry weight}}{\text{turgid weight}}$$

3.3.3 Mitotic index

Mitosis is the process that occurs during cell division. As dormancy deepens the mitotic activity declines. Thus mitotic activity might serve as an indicator of the onset of dormancy.

3.3.4 Hormone analysis

Dormancy induction and release are hormone mediated processes. Thus it should be possible to assess the status of dormancy by measuring concentrations of various dormancy regulating hormones.

3.3.5 Electrical resistance

There is some indication that there are cyclic seasonal changes in the electrical resistance of the inner bark of some species. i.e., decreasing from spring to summer and increasing from summer through autumn.

3.3.6 Water relations

Most aspects of seedling physiology influence and are influenced by seedling water status. Thus, measurement of this characteristic may be of practical value in evaluating tree seedlings.

The status of water in a seedling reflects the imbalance between the rate at which water is absorbed by its roots and the rate at which it is transpired through the leaves.

Measurement techniques include;

- gravimetric method
- psychometric method
- density method
- freezing point depression method
- hydraulic press
- pressure chamber

3.3.7 Nutrient relations

Plant nutrition is a major topic in stock production. It is brought up in this discussion as a direct indicator of seedling quality. Two aspects of nutrition are considered here.

3.3.7.1 Mineral nutrients

Since all physiological processes as well as morphological ones are influenced by mineral nutrition, the nutrient status might be developed as an index of seedling quality. For example, N, P, and K affect various species differently with respect to frost hardiness and stress resistance. No consistent relationship has been demonstrated between any aspect of seedling nutrient content and seedling quality.

3.3.8 Food reserves

A measure of sugars, starch, hemi-celluloses, proteins, fats, oils and other compounds might be used as an indicator of seedling vigour. Unfortunately, the relationships have not been examined by systematic rigorous experimentation.

3.4 Seedling morphology

The most commonly cited morphological properties are those that are most easily measured: shoot height and weight, root system weight or volume, root fibrosity, stem diameter at the root collar, bud "set", foliage colour and various ratios such as shoot: root weight or top height: stem diameter. Although there are many generalizations and personal observations, comparisons of seedling performance based on morphological traits are valid only when seedlings are in the same physiological condition when tested. Some generalizations indicated that:

- seedlings with large stem calipers tend to out-perform those with smaller calipers
- large tree seedlings out perform small ones regardless of species or stock type.

Size alone is not meaningful if the seedling is out of balance. A large top requires a large root system to supply water and nutrients. Unfortunately, assessing the root volume is not a good indicator of the root systems' ability to provide the water and minerals.

At the Thunder Bay Forest Nursery we monitor and evaluate several of the seedling attributes discussed above in controlled plantings on the nursery. Results are included on the Stock Evaluation Form (Table 1).

Root growth potential of ship stock is evaluated in controlled plantings and measured after a couple of weeks.

Frost hardiness of transplants is determined by freezing treatments.

Dormancy has been tested on several occasions in preparation for the fall harvest using the oscilloscope method.

Water potential is monitored routinely using the pressure chamber method.

Nutritional status is evaluated through analysis of mineral nutrients.

Morphological characteristics are measured on representative samples from all stock shipped.

At our Nursery, efforts are concentrated on providing clients with stock that exceeds the minimum standards of height, root collar diameter and seedling fresh weight, has a desirable top to root ratio, is healthy and has no mechanical damage.

This intent has lead us to the commencement of production in controlled environment greenhouses and completion in compartments where optimum levels of moisture and fertility are maintained. With stock produced in this manner we are hearing reports of plantation establishment successes with up to 99% survival.

Table 1. Parameters considered in the quality monitoring of nursery stock at the Thunder Bay Forest Station.

Species Age Class Stock Lot # Seed Source Date Lifted Compartment	
District Destination	
Grading % Cull Defects	
Foliage Condition % with healthy green foliage % with 0-25% brown foliage % with 26-50% brown foliage % with 51-75% brown foliage % with 76-100% brown foliage	
Seedling Characteristics Height (cm) RCD (mm) RAI (cm^2) Shoot Dry Weight (g) Root Dry Weight (g) Total Dry Weight (g) Total Fresh Weight (g) Top/Root Ratio % Moisture Content Plant Moisture Stress (psi)	
Phenological Condition at Lifting (Shoot & Root) % seedlings with buds dormant % seedlings with buds swollen % seedlings with buds bursting % seedlings with small elongation % seedlings with extensive elongation	
Planting/Potting Results Date planted/potted Date assessed % Survival Survivors with height growth >3 cm C.A.H.I.	
Remarks and Notes	

3.4 Steps taken at Thunder Bay Forest Nursery to ensure stock quality from seed to ship

Efforts to produce a crop of the highest morphological and physiological quality begins with land preparation which precedes the seeding operation. Fertilization regimes on the nursery have been selected to produce a uniform crop of high quality stock. **Seeding density and depth** are extremely important factors in seedling germination. Before use, steps are taken to ensure the correct calibration of our seeders. Consistent and timely germination is the key to having a healthy uniform crop. Seed beds are mulched with a thin layer of commercial **mulch** applied as a slurry to prevent erosion of the seed beds before and during germination. Spruce seed beds are covered with **shades** to prevent excessive desiccation of the germinants.

After germination a close watch is kept on the germinants to ensure that the **moisture conditions** in the beds are conducive to growth, while at the same time avoiding excess moisture that could lead to damping off. Losses to damping off creates voids in beds that will result in greater variations in size in the final crop, as will the loss of vigour in those seedlings that survive the infection.

Through careful **soil amendments** and **top dressings** we have gone a long way toward minimizing losses due to under size stock. To ensure that good quality transplants are produced, seedlings lifted from the seedbeds for transplanting are **heavily culled and graded**. We endeavour to plant only the best seedlings since we believe that their superior characteristics will carry through to shipping and subsequent outplanting. Damaged seedlings are discarded, as are those that are undersized or malformed.

In an effort to **reduce the stress** placed on transplanted seedlings, only sufficient stock is lifted to complete one day's planting. This eliminates the necessity of stock having to be stored out of the ground for extended periods prior to transplanting. To further minimize stress on seedlings, they are placed in plastic tubs with moistened burlap placed between rows of seedlings to prevent desiccation while awaiting planting.

Transplants are watered within two hours of planting in order to close the planting slit, eliminate any potential air pockets and to preclude drought stress on the newly planted seedlings. When drought conditions exist, the transplant compartments are **thoroughly irrigated** prior to planting and again after transplanting is completed.

Transplant beds deemed to be at risk of frost heaving are **mulched** in the fall to prevent frost heaving. Heaving often will result in stem deformation ('J' stem). At the Thunder Bay Nursery, peat is used as the mulching medium, and is applied approximately one inch deep.

A **root wrenching program** is followed to influence the morphology of several stock types. In black spruce, root wrenching is carried out to encourage the formation of a more fibrous root system, and to lower the top to shoot ratio. In jack pine, root wrenching serves to promote a more fibrous root system, and retards the growth of the elongating shoot to produce a shorter seedling, the net result being a lower top to root ratio.

An **electrical impedance monitoring program** has been undertaken on nursery stock as it is lifted in the fall for overwinter frozen storage under the direction of our Research Branch. Electrical impedance monitoring has proven to be a reliable method of determining the dormancy of seedling stock, which has allowed us to establish a window for fall lifting of fully dormant stock. Dormant stock has been shown to withstand overwinter storage and handling much better than stock that is not dormant. This is reflected in higher survival and better growth rates in the field.

Stock lifted for shipping is graded to avoid shipping of deformed or damaged seedlings. Seedlings suffering any type of mechanical damage are not shipped. Mechanical damage includes skinned bark and badly stripped or torn roots. Precautions are taken at lifting time in order to **minimize mechanical damage** to seedlings; for example, pickers lift large bunches of trees rather than pulling single trees. This method of lifting significantly reduces the amount of mechanical damage done to the root system.

In order to reduce seedling stress and preserve physiological quality, a number of steps are taken to **reduce exposure** of the root systems to the elements during the lift for shipping or storage:

- i) spring lifting is planned in a manner that will allow lifting of all the stock while it is still in a dormant condition.
- ii) the EGEDAL lifters used to loosen the seedlings from the seed beds are adjusted to shake excess soil from the roots and lay the seedlings on the surface of the bed, yet leave sufficient soil over the roots to **prevent desiccation**. The beds are loosened only as they are picked, to minimize the time that seedlings could be exposed to the drying effects of wind and sun.
- iii) once the seedlings are picked and bundled, they are then immediately placed roots down in tubs, in which the trees are taken to the processing tables where they are **root pruned, dipped in water and packaged.**
- iv) speed is of the essence during lifting, and we expect that seedlings are lifted, **packed in boxes** and placed into the cold **storage** within one half hour.

Stock lifted for shipping is root pruned to a uniform length, primarily as an aid to planting. Through cultural practices, the remaining root system will be fibrous, and fully capable of assuring survival in the field.

Through our cultural practices we attempt to manipulate the morphological characteristics of the stock that we produce and throughout the process, many steps have been implemented to ensure good physiological quality. After the crop has been successfully grown, we have culling and grading rules in place ensuring that only the best of the crop is shipped to the field.

3.5 REFERENCES

Duryea, Mary L. and Thomas D. Landis (Eds). 1984. Forest Nursery Manual: Production of bareroot seedlings. Martinus Nijhoff/Dr. W. Junk Publishers. The Hague/Boston/Lancaster. 386 p.

Ritchie, G. A. 1984. Assessing seedling quality. PP243-260. In: Duryea, Mary L. and Thomas D. Landis (Eds). Forest Nursery Manual: Production of bareroot seedlings. Martinus Nijhoff/Dr. W. Junk Publishers. The Hague/Boston/Lancaster. 386 p.

4.0 OBSERVATIONS ON THE REFORESTATION AND SEEDLING PRODUCTION FOR CROWN LANDS IN NEW BRUNSWICK

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The reforestation project in the province of New Brunswick appears to be running quite satisfactorily.

This simple statement is based on several years of systematic observations of all plantations on the provincial crown land. Floating sample plots of five meter-radius, laid out according to sound statistical principles, are tallied 12 months after planting and again three and five years after planting. Considering all black spruce and jack pine seedlings planted for three consecutive years, mean survival at the end of the first and third years by species was 87 and 79 percent and 88 and 82 percent, respectively. Survival is, however, only a basic requirement. Our licence agreements specify a five year minimum target height of 75 cm for black spruce and 130 cm for jack pine (at 5 years).

This is background. I do not wish to appear smug - we are not without problems, but I think that we have overcome some basic difficulties. Generally, I feel that our major weaknesses are now in the planting sites rather than in the field of seedling production.

My basis for this comfortable assertion is the comprehensive body of performance records for the whole lot of crown land plantations. The overall average for our 1983 plantations, speaking of height development for black spruce paperpots, shows 12 cm initial height, 24 cm after 12 months and 49 cm at the age of three. Jack pine paperpots measured 10 cm initially, then 22 cm after 12 months and 70 cm at the end of the third growing season.

We have good results, but I find it tricky to explain why. Perhaps the following points will help clarify this.

First: The location - New Brunswick has a variable summer climate, often a disappointment to tourists, but good for trees. We can plant from late April until October. Survival and height development by planting month show better results from June and July than from May plantings.

New Brunswick is small enough that we just about know the fellows responsible for the rest of the reforestation process. We have a good direct contact with the people who plant our seedlings. This means that we can lean on them to take seedlings in their prime, and the clients can tell us if they find that we are short of the mark in regard to quality, quantity or shipping practices. We also insist that the foresters using our stock come to the nursery to survey the major lots in production.

Second: The quality of planting work - We have a longer planting season. This has a very significant effect in that a small number of planters are employed for a long season. This leads to higher quality planting. We have a goodly number of people who describe themselves as tree planters and come back year after year. They cherish this kind of work because it is a substantial source of income. Since they look at this as their livelihood they require less supervision and they are not playing games.

Third: Experience in raising seedlings - We have grown container seedlings for twenty years. During that time, we have made a lot of mistakes. We have learned from our errors where we could. If not, we repeated our mistakes until we found a way out. Like everybody else, we have some routines that we are sure of and others that we still dance around with.

As you know, we have used the paperpot system as our mainstay and this is still the case. We test other containers on the side, mainly to update our own opinions as to their respective merits. I will positively refrain from propounding my own subjective ideas concerning the 'umpteen' other containers. I should mention that our four years of trials with the jiffy forestry pellet have turned out so well that in the current year we will produce seven million seedlings in this container.

I am not going into details concerning our actual growing methods, for the reason that we really do not do anything radically different from what others growers do. Moreover, we change our ways from time to time. When problems appear, the solution is rarely to change containers, fertilizer brands or equipment. You may say that it is nearly always pilot error; in any case it is always faulty management!

Passing advice among growers is not easy. Specific prescriptions may be poorly presented and wrongly applied. Anyone who feels that he would like to look at what we think we are doing is welcome to visit our nurseries and extract whatever useful information they can.

I have been asked to say something about the wintering of half or full grown stock. We took a few severe beatings in years past, wintering seedlings. We are convinced that a cardinal point is to avoid exposure to winter winds. Snow cover is the simplest answer, but cannot be counted on. We have experimented with snow making and find it very awkward without an expensive system of frost free hydrants and compressed air lines.

Our solution has been to cut long narrow slots in the woods behind each nursery, less than 20 m wide and some 200 m long, running east-west. The surface is built up with gravel for drainage and overlaid by coarse sand for good contact with the bottom of our paperpot flats. We never overwinter any stock on pallets or in any way raised off the sand. The long strips stop the wind and promote an even snow layer. The intervening wooded belts provide side shade and make the snow last longer.

We have two favorite periods in which we set stock out to winter. The first option is to have everything in place by the end of August. We then get into a natural, gradual hardening rhythm but lose some growth. The preferred method is a variant of Steve Colombo's plan: to tend the summer crop in the greenhouses; by September to leach and cool the crop; in October we feed the budded seedlings (being very scrupulous about stray light). We may or may not provide any extra heat. If heat is used we are of course, very particular about a gradual cooling to near-freezing night temperatures before moving the crop out under the open sky. By November, we move out to the sheltered winter grounds.

I hesitate to say much of a specific nature about winter-hardiness. A couple of weeks ago our so-called Technical Committee of N.B. Nurserymen discussed this subject at length. It is evident that the profession harbors at lot of uncertainty in this area. Mostly we feel comfortable with modifications of extended greenhouse culture, to condition seedling tops for wintering.

The state of roots from any greenhouse crop is a very different matter. We realize that there is really no state of dormancy for roots. Even in the dead of winter (if that isn't an unfortunate choice of words) a few balmy days will tempt some roots into visible activity. This flexibility is of course also an advantage in so far as active roots will become inactive and less vulnerable to frost in a matter of a few days of gradually decreasing temperatures.

Some people find it paradoxical that top and root of a small seedling follow such different drummers. There is really no paradox here, as roots were never intended to put up with rapidly fluctuating air temperatures. It is clearly unnatural to move roots in small containers from a relatively warm location to a 20° colder environment. Containers standing shoulder to shoulder in a substantial bulk cool off slowly; when they sit tightly on a soft sandy surface they benefit from the dampening effect of latent ground heat.

There has been a lot of talk about the possibilities of raising cold-tolerance of roots by manipulating their nutritional or hormonal balance. It is a bit like looking for vaccine against frostbite, where the simpler solution is to provide insulation or to avoid exposure. In this connection, I must also give credit to the excellent cooperation that exists between the local Canadian Forest Service, the University of New Brunswick (Fredericton Campus) and the growers of tree seedlings. In addition, to a prompt and efficient medium and foliage analysis service, we also have a cold-hardiness testing facility (based on programmable freezers) and a root-growth capacity test program.

It may be argued that to determine the frost-hardiness of wintering seedlings is somewhat academic, since such results arrive too late to modify the conditioning process: some say that if the predictions are ominous all you achieve is a winter of miserable apprehension. Most will agree, however, that having standardized testing methods used year after year will, in the long run, allow us to take corrective action - to adapt our conditioning regimen.

Weeds have been our worst problem. We are tantalized by the existence of a very efficacious herbicide, Ronstar or Oxadiazon, which still isn't registered for use on our side of the border. We are, in cooperation with CFS, testing similar products such as Devrinol, Treflan and Goal. I said a while ago, that when reforestation problems occur, there is a strong tendency to look for explanations in the nursery end. This bothered me until I realized that this trend is due to the detailed records kept in the nursery. A body of facts such as seed provenance, fertilization records, greenhouse temperatures and growth measurements attract investigators, particularly because of the carefree lack of concrete data regarding site preparation, choice of species, quality of planting, management of competing vegetation, etc.

A typical page of the records for 1983 plantations shows a considerable variation in survival (after 1 & 3 years). For Jack Pine paperpots it runs from 43% to 100%. This stock was of one generation and one nursery in one season. I can guarantee that there is not such unevenness in the nursery stock; this variability must reflect very rough treatment after the seedlings were delivered. One might even say that since the nursery stock is subject to negative influences only after it leaves us, there's some justification in saying that all our seedlings have the potential for high survival when they leave us. It is certain that nothing that happens in the planting phase will increase the vigor of planting stock from, for example, 85% to 100% success; it must have been built in.

I have mentioned this angle not so much to make the nurseries appear nearly perfect; my point is really that we are all in the same boat with the same goals but that nurseries seem to invite scrutiny because our process is so well documented and our products so easy to measure in milligrams and centimeters.

I have strayed away from what I expected to comment on. I am not all sure that my remarks are of direct usefulness to you. Obviously I have no manual of cures and remedies. You should not get the impression that we in New Brunswick are without problems. Our current situation is that we have not had massive losses -- when things go well it is quite difficult to explain why this is so. I suddenly realize that it may be quite boring to hear about contentment and relative bliss. It may be high time to conclude these remarks. I reiterate my invitation to any grower who may wish to come and look into our practices.

5.0 CURRENT PRODUCTION TECHNIQUES IN THE PRIVATE SECTOR

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5.1 INTRODUCTION

There are many successful systems that are producing container stock throughout Canada and the World. The production techniques that I will describe pertain to the growing systems used in Northern Ontario and in particular Northeastern Ontario with which I am most familiar.

In the early 1980's the government of Ontario made the decision to increase the production of container stock in the province and to do so by encouraging the establishment of privately owned greenhouse complexes. It made the decision on what types of containers would be used, what types of cropping systems would be used, established a system for handling and allocating seed, crop monitoring, and shipping of seedlings to the field. So the private growers became established to fit within the framework that had been set up.

I will outline how we grow and will attempt to describe some of the techniques that we are using to improve the quality of the stock that we are producing. In Northern Ontario, three different crops of seedlings are being produced. They are current, overwinter double crop and overwinter single crop. In order to understand how and why these crops are different and what aspects of seedling growth we manipulate, we must first look at how a seedling grows. Figure 1 illustrates typical growth curves which can be expected for seedling shoot, dry weight and root collar diameter.

Germination - This is the period during which the seed absorbs water, swells and the radical emerges from the seed and pushes into the growing medium.

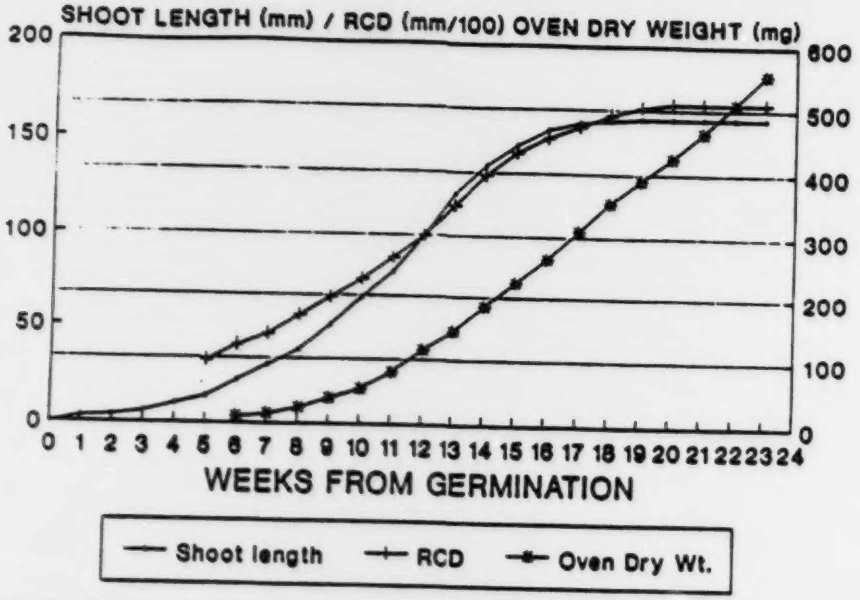

Figure 1. Typical growth progressions of shoot length, root collar diameter, and oven dry weight of an overwintered double crop of black spruce.

Juvenile Development - This stage begins when the food reserves in the seed are used up. It is basically a period of establishment.

Exponential Growth - This is the actively growing phase of development where a small change in time represents a large change in size.

With favourable temperatures and adequate amounts of light and moisture, the seedling will continue to grow taller. This stage ends when one or more of the factors becomes limiting and dormancy is induced. At this point, seedlings will be tall but quite slender, the foliage will be soft and limber and the upper part of the stem will be green and unlignified.

5.2 Bud development and lignification

Three very important changes occur during this period. Height growth stops and buds are developed. Needle primordia, which will constitute most if not all of the next years growth, are laid down during this period. Stem diameter increases and the stem becomes lignified. The physical appearance and the sturdiness of the stem change considerably.

Roots continue to grow and the shoot:root ratio decreases. At this point the seedlings are "summer dormant" and can withstand full sunlight, drought stress, wind and even a light frost.

5.3 Hardening

This phase occurs naturally after budset under conditions of short day length and low temperature and results in the trees being able to withstand winter conditions. When the stages of growth are related to the cropping schedule, the reasons for physical differences in the three crops becomes evident.

5.3.1 Current crops

Current crops are being produced by growers who sow two crops of trees per year. Double crop facilities have heating systems capable of maintaining 27°C temperatures during the coldest months of the year. The current crop is sown in January for black spruce and late February for jack pine. After germination, which takes approximately two weeks to complete, there is a period of approximately 13 weeks in which to actively grow the trees. This leaves a period of approximately 2 weeks for bud development and lignification. The current crop is planted in June and July of the same year.

5.3.2 Overwinter double crops

Seeding of this crop occurs as soon as the current crop has been moved outside. This crop can be actively grown until the last week of August, a period of approximately 9 - 10 weeks, at which time the bud initiation phase must begin to allow time for adequate hardening. These trees are planted the following spring.

5.3.3 Overwinter single crops

This crop, produced by growers whose greenhouses do not have heating capabilities, is seeded in mid to late April and more closely follows the natural growing season. The trees have a period of 15 weeks in which to actively grow. The trees are grown until the desired size parameters are met then one or more of the factors needed for growth are limited to initiate bud set. Bud initiation is difficult to initiate in mid summer when natural conditions still promote growth. If bud initiation is delayed, trees may become too large and may be subject to increased disease problems.

Both overwinter crops will be sturdier and have a more extensive root mass than the current crop because of the extended bud initiation and hardening periods. Figure 2 illustrates the timing of the above crop types over the course of a year.

An obvious question arises. Is one of these stock types superior or inferior to the others? In December of 1986, a seminar was held in Timmins - the topic was Stock Standards and Early Plantation Performance. Arising from this seminar was a series of trials that were initiated in 1987. Two of the trials concern container stock. The "Careful Planting Trial Series" has been established to compare such issues as single crop vs double crop and overwinter vs current crop. The "Client Series" of trials has been established to compare field performance of various stock types over a variety of site conditions. The trials will be carried out over a period of five years and last month the first year results were presented (Northern Forest Development Group, Timmins, 1988). The preliminary results have been of great interest to the growers. Because the data is only over one year, we can only make very general

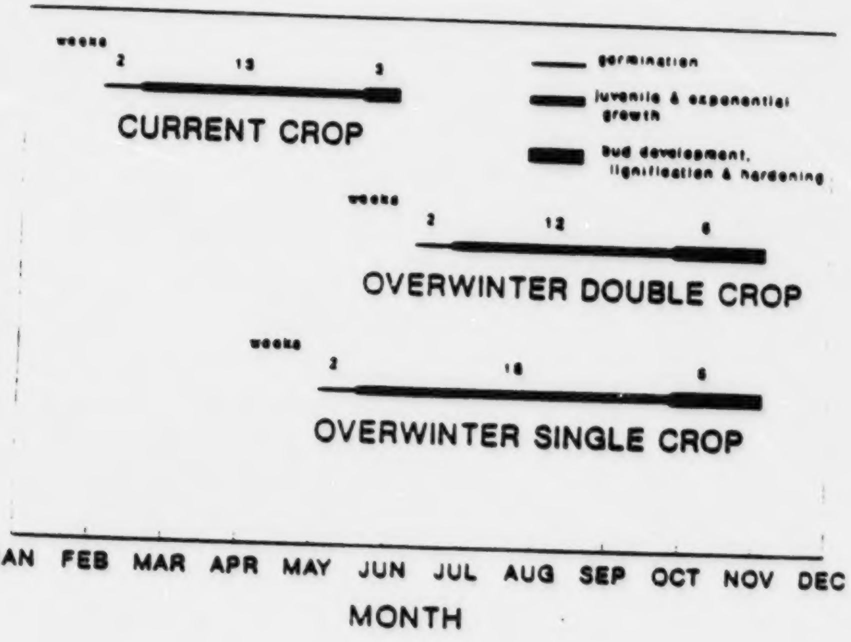

Figure 2. Timing of three black spruce crops produced by tree seedling growers in the Northern Region.

observations. What the Client Series Trials are indicating is that survival and C.A.I. of the same stock (i.e. from one grower) vary considerably on the different planting sites throughout the region. The first year results of the Careful Planting Trial are presented in Table 1. For overwinter black spruce - both single and double crop, there was no significant difference in the survival rates of any of the stock. Even more interesting is the range of C.A.I.-from 9.7 to 12.3 cm, a difference of 3.4 cm. A first year increment of 10 cm has been set as the goal for black spruce. In effect what we see based on one years data is that the 10 different greenhouse complexes are producing black spruce that is giving satisfactory results. We know that current stock does not produce height growth in the year that it is planted. The growth data from the second season which we will have next year will help determine how significant this is. Some growers have conducted trials where current stock is held in the holding area of the greenhouse complex during the summer of the first year and then planted as overwinter stock the following spring. For the purpose of the careful planting trial, this uniquely cultured and handled stock was planted with the normal current crops. Preliminary results have shown this stock outperformed the other normal overwintered crops. Despite these results, further improvements in stock production techniques are required, for we are concerned about the performance of all seedling crops.

Survival is probably the most basic area of concern, although for current crops mortality does not appear to be a problem. In the overwintered crops, overwintering losses have caused every grower some amount of grief. There are two types of overwintering losses. One is caused by abnormal or extreme natural conditions that healthy well conditioned seedlings cannot withstand. This situation brings up the need for cold storage facilities. If conditions are too severe to allow for the survival of a well conditioned seedling, then we must find alternative storage methods. The other type of losses are those suffered by seedlings that are not sufficiently conditioned to withstand normal winter conditions. This situation cannot be remedied through cold storage. We have conducted cold storage tests and found that trees that did not survive normal winter conditions also did not survive in cold storage. How do we condition these trees? One way is through a process called

TABLE 1. First year results from the Careful Planting trials in Black Spruce conducted under the auspices of the Stock Production Development Activity Committee of the Northern Forest Development Group, Timmins, Ontario.

Cultural Regime		Overwintered Black Spruce - Overall Performance		
Photo Period	Crop Type	Survival %	C.A.I.(cm)	Total Height(cm)
1 short day	single	97.1	12.3	29.5
2 short day	double	96.5	12.0	21.5
3 natural	double	95.1	11.9	23.2
4 natural	double	94.7	11.4	26.7
5 natural	single	94.4	11.3	28.2
6 natural	double	89.6	10.7	19.8
7 natural	double	96.9	10.2	20.8
8 natural	double	87.1	10.0	21.2
9 natural	single	96.1	9.8	25.8
10 natural	single	94.9	9.7	25.6

Cultural Regime		Current Black Spruce - Overall Performance		
Photo Period	Crop Type	Survival %	C.A.I.(cm)	Total Height(cm)
1 natural	double	94.7	12.4**	27.8
2 natural	double	99.6	0.0	16.9
3 natural	double	99.6	0.0	17.1
4 natural	double	99.2	0.0	22.9
5 short day	double	98.2	0.0	17.2
6 natural	double	99.6	0.0	17.1

** grown as current stock but overwintered and planted as current in following spring extended greenhouse culture. This procedure was introduced to eliminate the overwinter damage caused to shoots when the seedlings were moved outside and exposed to frost before significant hardening had taken place. Seedlings are left in the greenhouse under conditions of short photoperiod and warm temperatures. Frost hardiness levels are monitored and trees are not moved outside until acceptable levels of hardiness are reached. This process ensures that the shoot can withstand freezing temperatures without sustaining damage; however, it does not (even though it was modified in 1987 with a period of cold hardening) eliminate the problem of root damage. While we really do not fully understand the physiological mechanisms that affect root hardiness, we do know that it increases with the length of the hardening period after 100% bud set has been achieved. This is evidenced by the single crops which sustain less root damage. One system that is being used by more and more growers is short-day treatment. Once crops have obtained the desired morphological parameters, they are subjected to 8 hour days by completely blacking out the crop with some type of black out curtain. Bud set under these conditions occurs over a much shorter period of time than natural day length and the length of time for the hardening period is increased. Short day treatment also produces seedlings with larger buds and short day seedlings have been observed to grow for a longer period of time in the first year of outplanting than seedlings conditioned under natural day length. Some double crop growers are attempting to overcome the conditioning problems by modifying crop schedules with the use of cold frames. Current crops are sown as early as possible in January and then are moved into cold frames in April. Overwinter crops can then be grown on approximately the same schedule as single crops.

These procedures have outlined techniques for improving survival; however, crops are judged by end-users and growers receive payment based on morphological characteristics. This is height, root collar diameter, weight and associated ratios. It is not possible to discuss how we attempt to optimize these characteristics without first quantifying them. This is a most difficult task as there really is no consensus as to what these parameters should be. What is perceived as acceptable by one end user can be totally unacceptable to another. The management decisions made during the course of producing a crop of seedlings will influence the final product. One of the main problems that growers have faced to date is that they have been growing without a clear understanding of what the end user of the stock was looking for. We know that the preferences between end users varies considerably and whether we can - or even should - try to come to a consensus on stock parameters remains to be seen. A grower is only one link in a chain of events that starts with a cutting operation and includes seed collection, growing, handling, site preparation, planting and tending. In many instances, lack of communication, personal bias or prejudice has interfered with the success of the process. If the grower has a clear understanding of what the end users require, management decisions on individual crops can be based to suit the needs of the end user. The communication has to work both ways. What I would like to leave you with are some thoughts on areas of crop production that are not either well understood or accepted by end users.

The first is an area that I have already discussed and that concerns the reasons for the difference in sizes between crops (i.e. timing) and the reasons for the differences in current and overwinter stock. Too often we hear from the field that a load of current stock was received and it was too spindly and succulent. This usually occurs when the field staff has already received some loads of overwinter stock. Of course the current stock will look different. It hasn't had a hardening period - this will occur in the field once it has been planted.

The second point is that greenhouses are not growth chambers. We can control the growing environment to a certain degree - each different complex can control different environmental factors such as, temperature and humidity to different degrees. All complexes are affected in some way by the outside environment (temperature, sunlight, winds). There have been and will continue to be situations arising over which the grower has very little control. Crop irregularities caused by condensation drips or uneven germination caused by colder corners or edges are two examples that come to mind.

Thirdly, variability is an attribute inherent in the growing process yet growers find that it is rarely acknowledged as being normal. Crops will vary from year to year and trees within a crop will vary. Figure 3 illustrates the variability of crops produced in two successive years. There is no recipe that will produce every tree of exact quality and

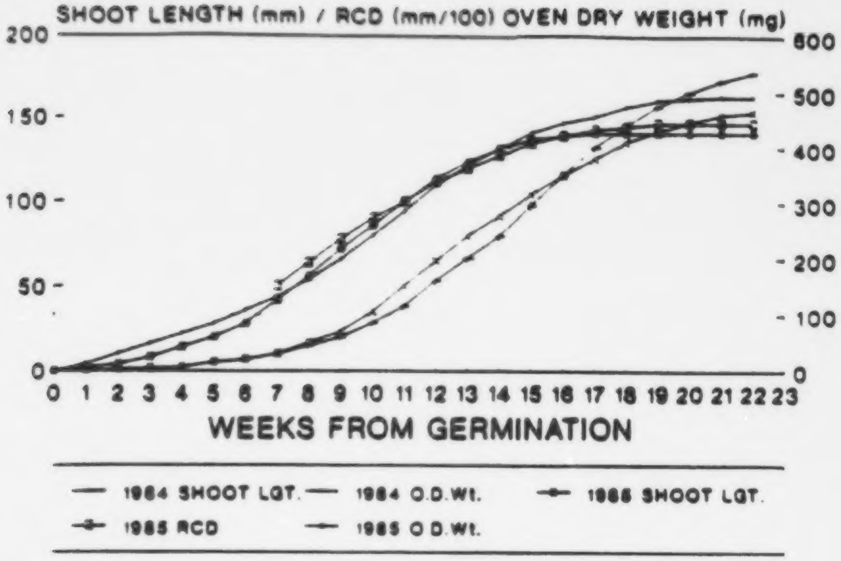

Figure 3. Variability in shoot length, root collar diameter and oven dry weight of two overwintered double black spruce crops.

dimension. An analysis conducted on the final inventory data for 1986 and 1987 crops grown in the Northern Region showed the variability within the crops was not caused by an individual's growing regime but rather was a function of the size of the crop. As the height, diameter, and height diameter ratios increased, so did the standard deviations (i.e. the magnitude of the variation) yet the coefficients of variation were approximately equal for all crops.

Lastly, we have to examine how we evaluate a crop of trees. Crops are judged upon, growers are paid upon morphological characteristics yet, (quote from paper written by researchers at Maple) size accounts for no more than 30% of a seedlings' performance after planting. The remaining 70% of a seedlings performance is determined by its physiological condition. We understand that the physiological condition of the stock is important and we know that through our growing techniques, we both knowingly and inadvertently, condition the stock yet - we do not have any operational standards or methods for measuring the physiological condition of the stock we produce. The remedy to this situation will have to come from the combined efforts of researchers, growers, and end users.

5.4 Conclusions

The production of container stock has come a long way in the past seven years. Much more is expected of the growers than it was in the early 80's and I believe that many growers have responded to that change and are becoming more involved with the research and development of new cultural techniques. Many growers are conducting trials covering all aspects of growing: pot size, fertilizer rates, outdoor storage methods, seedling thinning techniques. Communications between growers and all parties they deal with has and continues to improve. As Keith McClain indicated, it involves teamwork. Under these conditions the quality of the stock we produce will undoubtedly continue to improve as well.

BASIC SEEDLING PHYSIOLOGY : HANDLING

6.0 PHYSIOLOGICAL RAMIFICATIONS OF STRESS DURING HANDLING, STORAGE AND TRANSPORTATION OF SEEDLINGS

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6.1 INTRODUCTION

There are numerous opportunities for stress to seeds or seedlings between the time cones are collected and seedlings are planted. When the seed or seedling is stressed, it shifts its priorities from the metabolic processes[1] of development and growth to those responsible for adjustment and repair (Bazzaz *et al*. 1987, Bloom *et al*. 1985). Recovery to the prestressed condition requires time, energy, substrates[2] for repair, and the absence of further stress events (Chapin *et al*. 1987, Hoque 1982). Unfortunately, the potential for stress events is high during the reforestation process (DeYoe 1986). Those responsible for handling stock must take every precaution to insure that the frequency, duration, and intensity of stress events are minimized, and that any exposure to stress occurs when seedling resistance is high (DeYoe 1986, Duryea 1985b, Kauppi 1984).

Stress events registered by the seedling reflect imbalances and/or extremes in temperature, water, nutrients, light, soil and atmospheric chemistry, and physical conditions (Levitt 1980a, b). The initial impact on the seedling occurs at the cellular level, where the signal is received, translated into plant language, and expressed as a "stress" response.

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[1] The multitude of chemical reactions occurring in plant cells that are the essence of daily function.

[2] Representative of a wide array of chemical compounds in plant cells that are used in creating products designed for a specific purpose.

Maintaining stock health during handling will improve survival and growth. However, links in the "handling chain" weakened by poor planning will increase the likelihood that stresses inherent in the planting site will be detrimental. Site related stresses are expensive to minimize, difficult to predict, and become increasingly hazardous to the seedling as site quality deteriorates. Precautions for maintaining seedling health must begin during culture and continue through planting; otherwise, the risk of failure will be high, even on mild sites (DeYoe 1986; Tabbush 1986, 1987).

6.2 Seedling stress - easy to miss

If we cannot tell by looking at a person whether he is healthy or fighting the flu bug, should we expect to make that distinction in seedlings? Seedlings may look fit, but they may be experiencing serious physiological trauma. This is frequently the case when poor quality control has permitted handling practices to deteriorate. Most stresses arising from poor handling practices are subtle (Table 1), so that the seedling appears perfectly healthy until after planting, when site stresses assist in expressing true seedling status.

Seedling vigor tests provide a mechanism for assessing "invisible" damage and should be considered whenever poor seedling health is suspected (Duryea 1985a). Traditionally, tests for monitoring seedlings were conducted at the nursery before their transfer to the field. Consequently, abuses during transit, local storage, transports to the site, and planting were rarely registered.

Current research in Canada is providing physiological techniques for quick, reliable seedling evaluations (Colombo 1987, DeYoe and Drakeford 1987, Kim *et al*. 1987, Vidaver and Binder 1987). Beware! Trying to use one tool for all purposes is unrealistic. Would you feel secure having a doctor rely on a single test to assess your physiological status and

Table 1. Types of seedling stress and situations in which seedling stress can occur.

Stress	* late fall freeze that kills stem or roots * freeze-storage without proper freezing or thawing technique * freezing during site storage on upper-elevation sites
Desiccation	* root drying during lifting, temporary storage, and processing * drying due to vapour loss through holes in bags * condensation on inner surfaces of boxes in response to evaporative losses from heating during handling
Flooding	* transient waterlogging in container cavities during culture * exposure of roots to excess moisture * prolonged root dipping
Physical abuse	* transient waterlogging in container cavities during culture * simple handling of seedlings when stress resistance is low * root damage during lifting or processing * jarring or shaking bags/boxes during transit * slapping roots against an object to remove soil or ice prior to planting
Heating	* faulty cold storage facilities * transportation without refrigeration * local storage without refrigeration * transport to the site without proper insulation from radiation or heat sources

NOTE: Stress can be subtle. Individual or cumulative events can gradually reduce seedling vigor, yet never be noticed until after the occurrence of mild site stresses in spring.

"predict" your future performance?

Seedlings encounter an overwhelming number of stress events between cone collection and establishment. Seedlings are "infant" organisms: they are more sensitive to stress than "teenagers and adults", and less capable of recovering from multiple stress events. Hence, care must be taken at this early stage to ensure cost-effective reforestation.

6.3 Is stress cumulative?

Have you ever had a cold and been forced to work in cool, damp weather? This type of stress to your system frequently leads to upper respiratory infection. If you continue to push yourself instead of resting, pneumonia is the likely outcome. When this occurs it does not take much additional stress to cause death, particularly in a young infant.

When one stress after another is encountered from the time the seed (an encased embryo) is collected to the time the seedling (a developing infant) is established, the consequences of cumulative stress can be devastating. The lack of appreciable recovery time between stress events interrupts the "healing" process and aggravates the situation. (Would you rather twist your knee at the beginning, or the end, of the rugby season?

The problem confronting us now is perception. We simply need a better understanding of stress in tree seedlings. We need to know what constitutes a stress event, what is required for recovery, and how to re-synchronize seedling development. Being aware of stress and how it affects plants is the first step. To accomplish this, we need to probe the seedling to see what makes it tick (Kozlowski 1979; Levitt 1980a, b).

6.4 To the source - the cell

Figure 1 shows a plant cell in cross section (Kramer and Kozlowski 1979, Lehninger 1982). The *cell wall* provides each cell with the skeletal structure that allows the seedling to support itself vertically. Inside the wall is the *cell membrane*, which confines the cell solution. The cell solution, or *cytoplasm*, contains a variety of ions and solutes[3], important cell regulators (DNA, enzymes, pigments, etc.) and membrane-bound organelles.

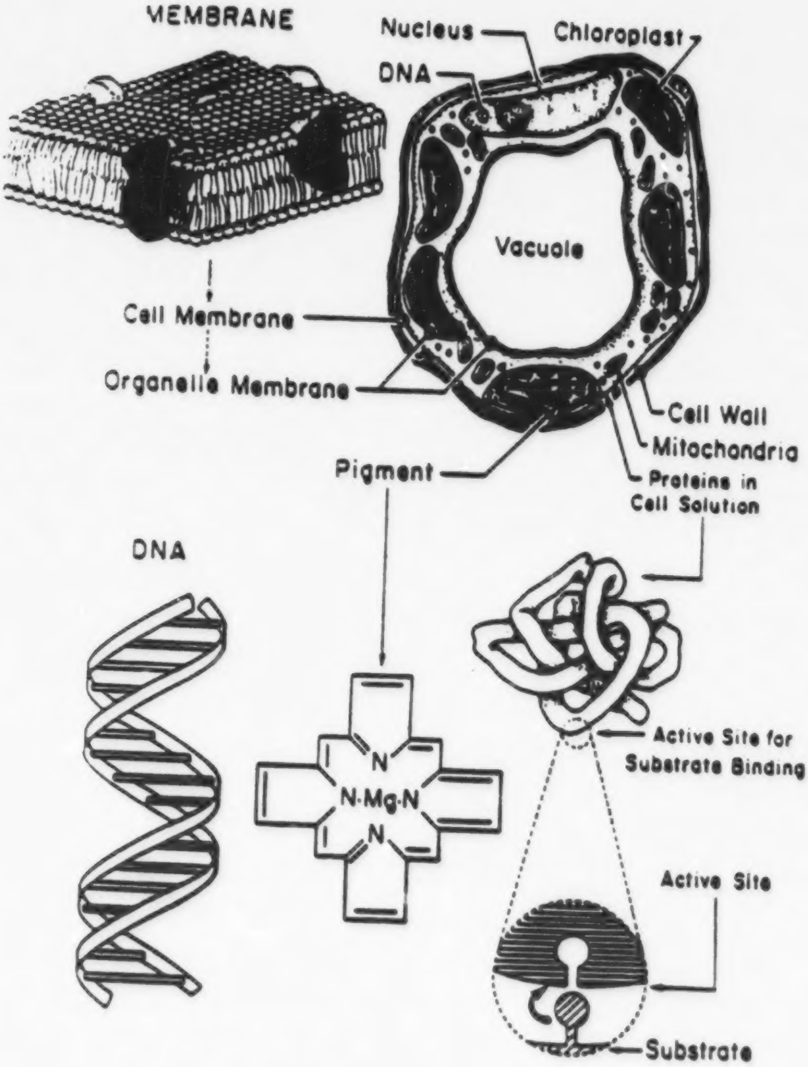
MEMBRANE
Nucleus
Chloroplast
DNA
Vacuole
Cell Membrane
Organelle Membrane
Cell Wall
Mitochondria
Pigment
Proteins in Cell Solution
DNA
N
N·Mg·N
N
Active Site for Substrate Binding
Active Site
Substrate

Figure 1. A mesophyll, or photosynthetic cell found in conifer needles.

The organelles include:

- the *nucleus*, the source of genetic information
- the *chloroplast*, where light energy is converted to chemical energy that the plant can use to produce food from carbon dioxide and water
- the *mitochondrion*, where food is processed to generate energy and heat
- the *vacuole*, where a wealth of components, serving a variety of functions and potentially toxic to cytoplasmic regulation, is housed.

Embedded in cell and organelle membranes are "transporters", proteins that control cellular traffic.

Think of the cell wall as a hollow sphere of steel wool. Inside this sphere is a water filled balloon; the skin represents the cell membrane, the water represents the cell solution. Suspended in this water-filled balloon are numerous smaller water-filled balloons, representing organelles with their own membranes and organelle solutions. The transporters would appear as small beads, scattered across and transcending the balloon's skin, their colour and shape signifying transport specificity.

6.5 How does the cell respond to the environment?

This finely compartmentalized cell (Figure 1) is not so different from the cells that make up our bodies (Lehninger 1982). It can work independently, but *must* keep in step with other cells if the organism is to function properly.

6.5.1 Seedling response to environmental signals

The signals to which the seedling responds are represented by the chemical and physical characteristics of its immediate environment--water, light, temperature, atmosphere, soil chemistry and structure, wind, mechanical disturbance, etc. (Kozlowski 1979; Levitt 1980a,b). These factors inform the seedling of minute-to-minute changes in the environment, so that it can continually adjust and maintain efficient

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[3] Sugars, amino acids, proteins, and other carbon-based compounds dissolved in the cell solution.

daily operation. They also provide early warning of impending seasonal trends in the environment, and allow the seedling to prepare for major shifts in climate. The seedling has evolved to the point at which it can receive the appropriate signals and deal with them internally, subsequently adjusting to and tolerating, within limits, extreme climatic events.

Coordination within the organism is mediated by cell regulators. These regulators respond to environmental signals and facilitate the physiological and morphological changes that enable the seedling to cope with its dynamic environment. Cell regulators that respond to specific qualitative and quantitative aspects of environmental cues and are most sensitive to stress include membranes, proteins, DNA, and pigments. Figure 2 shows how these regulators, along with hormones and secondary messengers, fit into a signal/response pathway.

Manipulation of seedlings between lifting and planting greatly increases exposure to stress. Since stress triggers metabolic responses that override or compete with development and growth metabolism, the seedling can suffer a setback (Hoque 1982, Bloom *et al*. 1985, Bazzaz *et al*. 1987). The result is a delay in achieving developmental goals, such as seed maturation, acclimation to frost, development of leaf primordia, etc. (Poljakoff-Mayber 1981, DeYoe and MacDonald 1987).

6.5.2 The role of stress-sensitive cell regulators

Increased understanding of the regulators' role, their sensitivity to stress and the impact of setbacks on survival and growth potential is an important step toward prevention of stress-induced growth loss.

The ***membrane*** is responsible for cell compartmentalization, mediation of traffic flow within and between cells, and facilitation of energy production (Singer 1974, Eisenman 1987). As "traffic controller", the membrane regulates what goes in and out of the cell or organelle. Transport specificity is achieved by protein transporters embedded in the membrane. These transporters help coordinate the flow of ions, solutes, and cell regulators in response to external and internal cues. Each transporter is responsible for a specific compound or class of compounds. When membrane permeability is altered the changes in cell or organelle

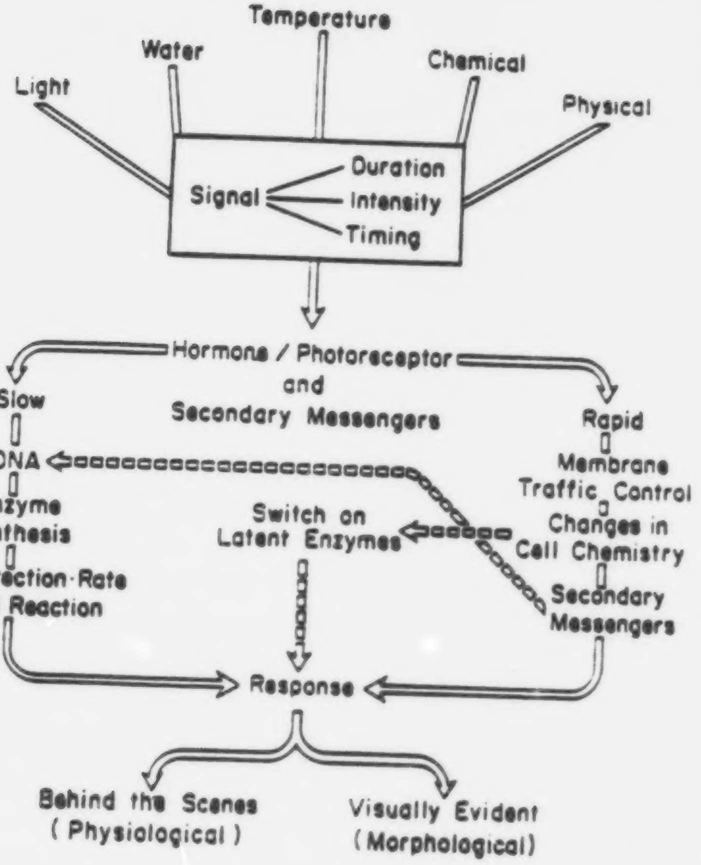
Temperature
Water
Chemical
Light
Physical
Signal
Duration
Intensity
Timing
Hormone / Photoreceptor and Secondary Messengers
Slow
Rapid
DNA
Membrane Traffic Control
Enzyme Synthesis
Switch on Latent Enzymes
Changes in Cell Chemistry
Type·Direction·Rate of Cell Reaction
Secondary Messengers
Response
Behind the Scenes (Physiological)
Visually Evident (Morphological)

Figure 2. The signal/response pathway depicts major events that are likely to occur as a seedling responds to its environment.

chemistry can have a pronounced effect on the direction of cellular metabolism (Helper and Wayne 1985, Berridge 1987).

Pigments are photoreceptors, responsible for capturing light energy (Ninnemann 1980, Smith 1982). The fate of this energy depends on the absorbing pigment. The photoreceptors responsible for capturing light energy to do seedling work include the photosynthetic pigment, chlorophyll, and the photomorphogenic pigments, phytochrome, the carotenoids, and the flavins. Chlorophyll absorbs light that is converted to chemical energy the plant can use to produce food and metabolic substrates. The photomorphogenic pigments use the energy in light to initiate a variety of developmental processes, such as stomatal opening, dormancy induction, flowering, cuticle formation, etc., which are part of gene-related action[4]. Hormones and/or secondary messengers act as mediators in most of these processes (Figure 2) (Sachs and Tuan-Hua 1986). Pigment destruction reduces or eliminates absorption of the light signal needed to drive these and other processes (Caldwell 1981, Powles 1984).

Messages arriving at the nucleus are translated by DNA into language that the plant understands. Loss of DNA integrity results in the production of nonsense words or phrases, or no response at all (Lehninger 1982, Kuhlemeir *et al*. 1987).

The words or phrases generated by DNA are in the form of special proteins called ***enzymes*** (Lehninger 1982, Cech 1986, Kuhlemeir *et al*. 1987). Enzymes provide the vocabulary the cell needs to determine what has to be accomplished metabolically. Enzymes work individually or in series, catalyzing cellular reactions that convert substrates into products[5]. The culmination of an enzyme-mediated process, which can be long and arduous, is expressed physiologically (by mobilization of food reserves, nutrient reallocation, cell membrane adjustments, etc) or morphologically (by wax deposition, leaf coloration, bud burst, lenticel development, etc.).

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[4] The DNA molecule is composed of hundreds of genes which, individually or in small groups, code for synthesis of a specific enzyme.

[5] Substrate-to-product conversions: the synthesis of starch (product) from thousands of glucose molecules (substrate), or breakdown of protein (substrate) into hundreds of amino acid molecules (products).

It should be evident by now that each of these sensitive cell regulators plays an integral part in the normal business of the cell (Figure 2). If the activity of any one is impaired, the whole system suffers. (How many links on your bicycle chain need to break to enhance the thrill of your downhill ride?)

6.6 What are the impacts of stress at the cellular level?

Healthy seedlings stay in tune with their surroundings, shifting as often as is necessary to maintain balance, both physiologically and morphologically. Environmental signals that register as "stress" set in motion a number of cellular responses, some designed to warn adjacent cells/tissues of impending disaster, others responsible for cellular adjustment and/or repair. Although many of the pieces of the stress puzzle await discovery, one thing is certain--stress is an expensive process, both biologically and economically (Larcher 1983, Bloom *et al.* 1985, Chapin *et al.* 1987). The use of the seedling's resource pool for adjustment and repair limits the availability of resources for development and growth. If stress-induced delays occur during critical developmental transitions (dormancy induction, frost hardening or de-hardening, flowering, bud flush, spring root growth, etc.), the risk of planting failure, and its associated costs, will be high.

6.6.1 Cell response to temperature extremes

Needle, bud and stem tissues of temperate species adjust quickly at the cellular level to daily and seasonal temperature variation (Levitt 1980a, Sakai and Larcher 1987). These adjustments help ensure maintenance of metabolic integrity. This is important because enzymes and DNA function optimally within a relatively narrow temperature range. Outside this range, activity declines. Membrane chemistry is also closely linked to temperature, continually adjusting to retain permeability by maintaining a constant viscosity (Chapman 1975).

Root tissues acclimate, but to a lesser degree than above ground tissues (Levitt 1980a, Lindstrom 1986). Since the soil environment is buffered against fluctuation and/or extremes in temperature, cellular adjustments in roots are limited and sluggish. Consequently, root tissues are very susceptible to damage between lifting and planting; they are like fish out of water.

High temperatures weaken the structure of DNA and enzymes, causing them to denature (unravel) (Tanford 1961, Raison *et al*. 1981, Teeri 1981). Activity declines or is lost. Cooling may reverse this action (Figure 3). If temperatures exceed 55°C, these cell regulators are destroyed and the cell/tissue dies. You actually observe protein denaturation every time you fry an egg--the translucent portion turns white.

Mild freezing temperatures cause ice to form between cells and in the cell wall (Figure 4). Ice has a very low vapour pressure, not unlike the air in the desert on a hot summer day. Consequently, water in the cells that is not bound tightly to solutes or membrane surfaces is pulled from the cell towards the growing ice crystals. This dehydrates the cell (Steponkus 1984, Sakai and Larcher 1987).

Cell dehydration is caused by loss of water from the cell/organelle solution. When this occurs the solution becomes concentrated, changing its chemical character. Ions and/or solutes that were once "friendly" may now limit the catalytic activity of enzymes, or stiffen the membrane, altering its ability to regulate traffic flow or mediate energy production.

The impact of "freeze desiccation" on cell regulators is analogous to that caused by drought stress (Figure 4) (Siminovitch and Cloutier 1983). Further, just as fall rains allow rehydration of cells desiccated by drought, *slow* thawing allows meltwater from ice crystals to reenter the cells. I emphasize the word "*slow*" because membranes require time to adjust to temperature change (Steponkus 1984).

Seasonal ***freeze/thaw events*** in spring and fall, or during storage and transit, can be devastating if seedlings are not sufficiently cold-hardy (DeYoe and Brown 1979, Oquist and Martin 1986, Sakai and Larcher 1987). Damage is typically associated with tissue death that results from loss of membrane integrity. Have you ever handled a head of lettuce after it has been frozen and thawed?

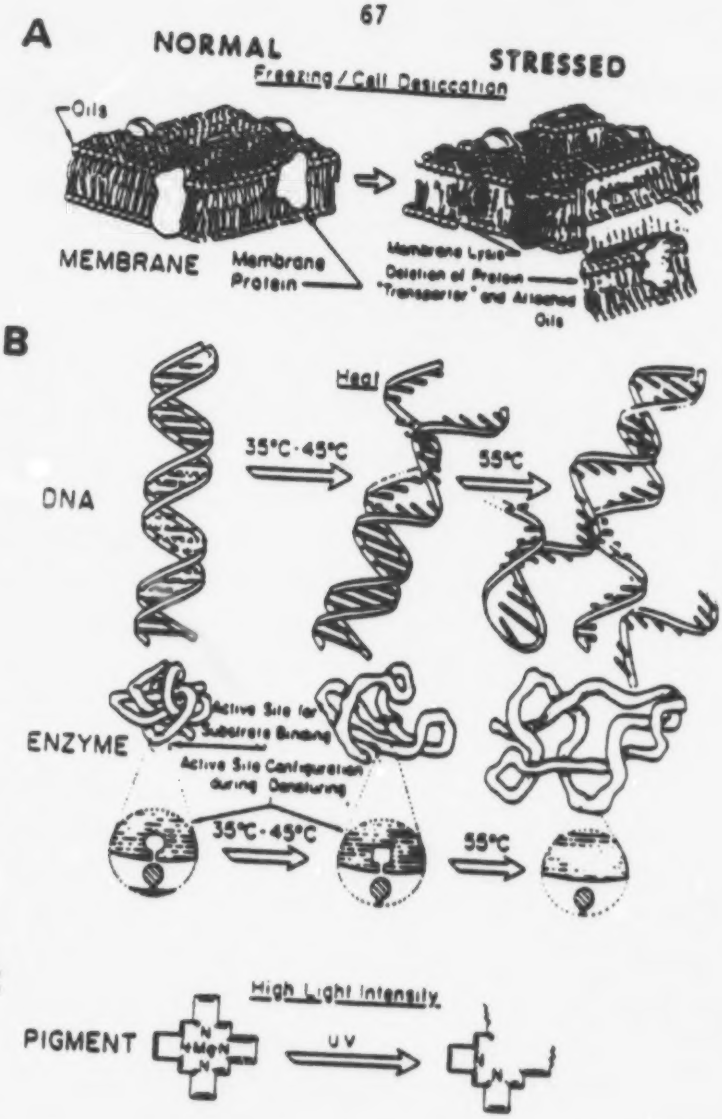
A
NORMAL
STRESSED
Freezing / Cell Desiccation
Oils
MEMBRANE
Membrane Protein
Membrane Lysis
Deletion of Protein "Transporter" and Attached Oils
B
Heat
DNA
35°C-45°C
55°C
ENZYME
Active Site for Substrate Binding
Active Site Configuration during Denaturing
35°C-45°C
55°C
C
High Light Intensity
PIGMENT
N
Mg
N
N
N
UV
N
N

Figure 3. Response of sensitive cell regulators to stress.

a. Freezing--Membranes: The membrane is a bilayer of fatty acids, with a texture similar to that of a film of oil. Like any oil, as temperature decreases, the membrane becomes more viscous, and eventually solidifies. At this point, or during thawing, the membrane cracks, cellular integrity is lost, and the cell dies.

b. Heat--DNA and enzymes: The intricate, three-demensional structure of DNA and all enzymes provides the specificity required for activity. Heat weakens internal bonding, causing unraveling and loss of activity.

c. Light--Pigments (DNA and Enzymes): The energy of ultra-violet and blue light can be sufficiently high to rupture chemical bonding between elements of a molecule. Note the nutrient requirement of the chlorophyll molecule for magnesium (Mg).

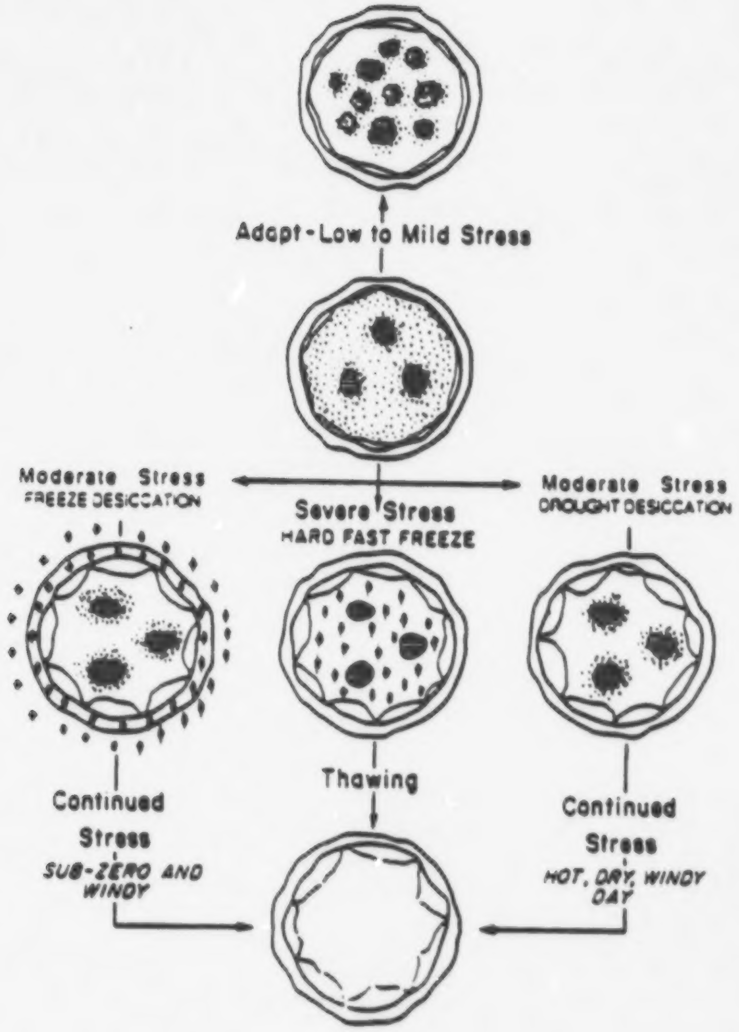
Adapt - Low to Mild Stress
Moderate Stress
FREEZE DESICCATION
Severe Stress
HARD FAST FREEZE
Moderate Stress
DROUGHT DESICCATION
Continued
Stress
SUB-ZERO AND WINDY
Thawing
Continued
Stress
HOT, DRY, WINDY DAY

Figure 4. Response of the cell to desiccation stress: Cells adapt to desiccating conditions by minimizing water loss (osmotic adjustment). Desiccation stress caused by freezing, or drought, reduces cell volume and concentrates the cell solution. If stress is too severe, membrane lysis will occur, killing the cell.

(·:·) = water molecules. (*) = ice crystals.

When *severe freezing* reduces temperatures below the cold hardiness threshold of the seedling tissues, whether the bud, the roots, or the stem, the cell solution crystallizes. Membrane rupture occurs and the cell contents are released during thawing (Figure 3a and 4). Different tissues have different degrees of cold hardiness and the tolerance of one may vary seasonally in relation to another (Tinus 1986). Consequently, the tissue with the least tolerance at a particular time may dictate the fate of the seedling. Needles and buds of Douglas-fir can be hardy at temperatures as low as -15°C, while stems are killed at 7°C, or less, depending on cultural treatment (DeYoe and MacDonald 1987).

Cells avoid freezing by deep supercooling (Burke *et al*. 1976, Sakai and Larcher 1987) or by adjusting their solute/water balance (osmotic adjustment) (Borowitzka 1981, Siminovitch and Cloutier 1983). Deep supercooling physically prevents ice crystal entry by impeding intracellular ice nucleation and by blocking seeding of extracellular ice via the cell membrane and wax-impregnated cell walls of certain tissue types (buds, xylem rays, and xylem parenchyma). The small, compact character of the cells within these tissue types further inhibits ice nucleation until very low temperatures are reached (-20°C to -40°C, depending on species and/or origin) (Burke *et al*. 1976).

Adjusting solute/water balance involves increasing the availability of solutes capable of tightly binding water so that losses are minimized. A portion of cell water must be lost quickly to prevent formation of intracellular ice. Excessive water loss must be prevented. In essence, the cell is striving to maintain sufficient turgor[6] to drive developmental processes by minimizing water loss (Tanford 1961, Levitt 1980b, Borowitzka 1981). Water is held so tightly by new solutes that it cannot be pulled away by the evaporative (low vapour pressure) demands of extracellular ice (or hot, dry air in summer) (Figure 4). Changes in the membrane that facilitate release of water and entry of solutes occur simultaneously and are critical to success (Chapman 1975, Steponkus 1984).

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[6] When the cell membrane is snug against the cell wall, the cell is at full turgor. As the cell dehydrates, the membrane pulls away from the wall. Loss of protoplast (Cell without the wall) volume and increased solution concentration reduce activity of cell regulators. Turgor is maintained by osmotic adjustment (Figure 4), or by loosening of the wall fibers so that it can collapse with the shrinking protoplast.

Metabolically, these adaptive processes are expensive, requiring considerable energy, substrate, and time to prepare the seedling to survive temperature extremes (Bloom *et al*. 1985, Gale and Zeroni 1985). Improper culture and handling practices force seedlings to waste valuable resources on numerous, abundant stresses that can be avoided more easily and at lower cost than stresses inherent to microsites on forest plantations.

6.6.2 Cellular response to extremes in moisture status

Shifts in cell/organelle pH (acidity) that occur during dehydration are common. Since DNA and many proteins (enzymes, membrane transporters, etc.) function optimally within a fairly narrow pH range, the effects can be dramatic (Smith and Raven 1979, Lehninger 1982). Although dehydration-induced shifts in pH or ionic strength reduce the activity of existing enzymes, the activation or synthesis of adjustment and repair enzymes will occur (Adams and Rinne 1982, Sachs and Tuan-Hua 1986). However, if dehydration stress is severe, the membrane may rip as it becomes more rigid or as it pulls away from the cell wall during water loss (Figure 3a and 4). The result is cell death.

Seedlings survive drought, at the cellular level, in much the same way that they tolerate freeze desiccation, by adjusting their solute/water balance (Siminovitch and Cloutier 1983, Morgan 1984) (Figure 4). Water loss is minimized by the production of solutes with high water-binding capacity. This helps keep the cell turgid and the membrane tight against the cell wall, both of which are necessary to minimize loss of metabolic activity caused by the effects of dehydration on the cell solution. Turgor pressure can also be maintained by relaxing the cell wall as water is lost (Jones *et al*. 1981, Teskey and Hinckley 1986).

Seedlings may also expend considerable energy and substrates in creating morphological features that reduce desiccation (Levitt 1980b, Turner and Kramer 1981). Expensive root systems, heavy wax deposits on leaves or in stomatal cavities, and orientation of needles toward the light are a few mechanisms used to avoid cellular dehydration.

"Flooding" refers to waterlogging of plant roots and describes the depletion of oxygen in water caused by microbes and plant roots. Oxygen is required for aerobic respiration in all living cells. Oxygen depletion shifts respiration from an aerobic to an anaerobic mode. Cells continue to use food reserves, but the major products now are heat and substances that are potentially disruptive to the cell (Kimmerer and Kozlowski 1982, Kozlowski 1984). Several of these substances are capable of disrupting the permeability of cellular membranes and altering enzyme activity. If you have ever hyperventilated when excited, or experienced muscle cramps while exercising, then you know what it feels like to be short of oxygen.

Visually, oxygen depletion is expressed by needle and/or stem epinasty (swirling or twisting) and needle yellowing. This is followed by tip dieback and crown desiccation as root mortality increases (Kozlowski 1984, Langerud and Sanvik 1987). Have you ever watched an over watered house plant become curly and crispy?

Seedlings adjust to oxygen depletion by using both morphological and physiological strategies (Kozlowski 1984). Morphological adaptations include the formation and/or swelling of lenticels, adventitious root production on submerged portions of the stem, and development of aerenchyma tissue (which permits freer movement of gases in stems). These strategies avoid oxygen deficiency by facilitating oxygen transport to root tips to maintain respiration, and stimulate uptake of water and nutrients for new root tip growth.

Physiological adaptations to oxygen deficiency help shift cell metabolism toward alternative pathways of energy production and/or conservation. The focus on energy is essential, for it buys the seedling time to make the "energy expensive" structural adjustments needed to increase oxygen access.

6.6.3 Cellular response to physical abuse

Physical stresses include wounding, compression (squeezing), tension (stretching), torque (twisting), and vibration (impacts) (Jaffe 1980). All trigger a rapid rise in respiration and adjustments in membrane permeability, which facilitate changes in cellular chemistry (Figure 5).

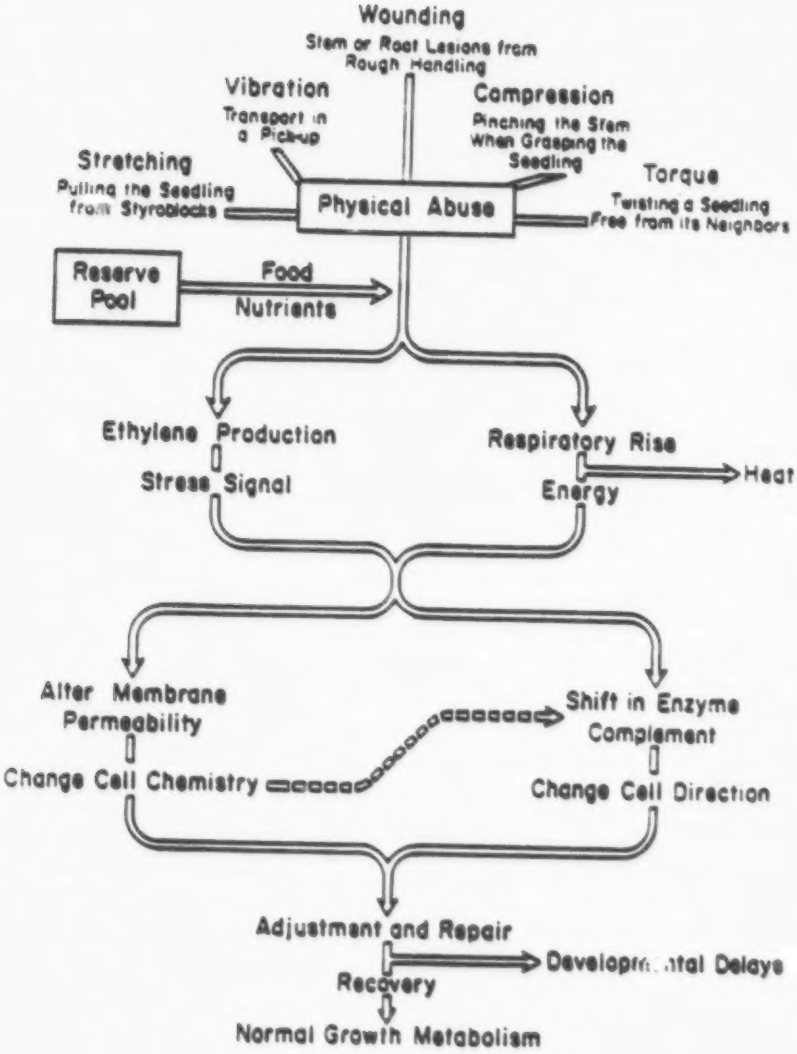
Wounding
Stem or Root Lesions from Rough Handling
Vibration
Transport in a Pick-up
Compression
Pinching the Stem When Grasping the Seedling
Stretching
Pulling the Seedling from Styroblocks
Physical Abuse
Torque
Twisting a Seedling Free from its Neighbors
Reserve Pool
Food
Nutrients
Ethylene Production
Stress Signal
Respiratory Rise
Energy
Heat
Alter Membrane Permeability
Change Cell Chemistry
Shift in Enzyme Complement
Change Cell Direction
Adjustment and Repair
Recovery
Developmental Delays
Normal Growth Metabolism

Figure 5. Response of the cell to physical abuse. The seedling is quite sensitive to physical stimuli. Each disturbance triggers a response. A sequence of physical stresses can have cumulative effects, particularly if insufficient time is allowed for recovery.

Within a brief period, ethylene[7] levels increase. Ethylene is associated with the transition from developmental to stress metabolism.

The stress/injury response involves adjustments in membrane composition and structure and in the complement of enzymes in cell and organelle solutions (Figure 5). These modifications help drive adjustment and repair processes. They occur after each physical stress event, and the effects may be cumulative (Levitt 1980a, b; Kauppi 1984).

Cumulative effects are extremely important between lifting and planting because the probability of multiple stress events is so high, and the seedling is extremely vulnerable. How does a boxer feel after one fight, 20 fights, 100 fights...? Have you ever heard the expression "punch-drunk?"

The metabolic costs of adjustment and repair are high. To complicate matters, the risk of stress is highest between lifting and planting when seedlings are unable to generate the food or attain the nutrient levels needed for rapid recovery. All demands must be met by using a limited pool of stored reserves.

If lift/store/plant regimes are conducted during the period of maximum stress resistance in the winter dormancy cycle, stress to the seedling can be minimized. However, if these operations occur outside the period of high resistance, the risk of stress increases significantly. Although survival may not be affected, growth will be reduced (Kauppi 1984; Tabbush 1986, 1987; Dunsworth 1987).

The period of maximum stress resistance varies with species and origin (Levitt 1980a, b; Tinus 1986). Determining a "stress-resistance window" for each species is the first step in identifying lift/store/plant regimes that will minimize stress to seedlings. Monitoring seedling response between lifting and planting can help target *safe* handling practices.

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[7] Ethylene is a gaseous hormone intimately involved in general stress metabolism. It seems to act as an early warning signal of cell or tissue disruption. Its gaseous nature facilitates rapid dissemination of stress information to adjacent cells and/or tissues. The information plays a role in triggering the shift from development and growth to adjustment and repair.

It is unfortunate that seedlings are not prepared to deal quickly and specifically with physical abuse. But how could Mother Nature have known about the hazards between lifting and planting during her evolutionary work with the tree?

6.6.4 Cellular response to light extremes

Seedlings are rarely exposed to extremes in light intensity or to ultra-violet radiation prior to planting. In nurseries in which exposure to high energy light does occur, frequent irrigation and fertilization facilitate the adaptations that protect seedlings from damage[8] (Smith 1982). It is a different story for the planted seedling, whose ability to adjust quickly to light conditions can be jeopardized by handling history and confounding site extremes. Consequently, the seedling's ability to cope with the light intensity characteristic of openings, particularly at high elevations, may by reduced.

A subtle but important consideration after planting involves the manner in which other types of stress combine synergistically with high-energy light stress to disrupt cellular function (Caldwell 1981, Powles 1984). This has profound implications for seedlings placed in open clearcuts, particularly if they have experienced improper culture or poor handling, or are not genetically prepared to cope.

Pigments are sensitive to light intensity (Figure 3c). Exposure of shade needles to high light intensity, or of sun needles to extremes in light intensity, can cause destruction of pigment. This may happen slowly by alteration of the natural balance of pigment turnover so that destruction exceeds synthesis (photo-bleaching), or quickly by molecular mutilation (photo-oxidation) (Caldwell 1981, Powles 1984).

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[8] A question yet to be resolved concerns the consequences of planting seedlings grown in low-elevation nurseries (<200 m) on high-elevation sites (>2000 m). Do low-elevation "signals" adequately prepare seedlings for extremes of light, cold, wind, and desiccation (Tranquillini 1979)?

When light intensity is too low, pigments cannot absorb enough energy to drive associated processes (Boardman 1977). Food production rates decline, respiration increases and tissue starvation ensues. This is what happens to interior crown needles as canopies close in a styroblock or in a forest stand. It can also occur in storage if temperatures do not stay cold.

6.6.5 Response to extremes in nutrition

Fortunately, seedlings are normally well nourished when they are lifted. Unless unreasonable demands are placed on seedlings because of stresses encountered between lifting and planting, their nutrient capital is normally sufficient to support survival and growth in the first season. However, if seedling nutrition in the nursery is inadequate, stress after lifting will influence allocation. Because nutrients are an integral part of cell structure and function, depletion of the pool to accommodate stress induced needs will reduce the accessibility of nutrients for development and growth.

Nutrients are part of the structure of enzymes (nitrogen and sulfur), DNA (nitrogen), membranes (phosphorus and/or sulfur), and pigments (chlorophyll - nitrogen and magnesium, and phytochrome - nitrogen and zinc) (Hewitt and Smith 1975). Furthermore, many enzymes require different nutrients as co-factors to facilitate enzymatic conversion of substrates to products. For example, alpha amylase requires calcium to assist in the breakdown of starch into sugar. For you potato lovers, the alpha amylase in human beings requires chloride!

Because nutrients are so important to metabolism and the risks of shortages in nature are so great, conifers have evolved efficient mechanisms to store and/or internally cycle nutrients to permit survival (Larcher 1983, Ingestad and Lund 1986). Seedlings also use the ratio of carbon to nitrogen as an internal signal to establish priorities for growth allocation (poor nutrition - grow roots; low on food - grow crown) and production of chemicals to defend against insect and fungal attack (Bazzaz *et al*. 1987, Chapin *et al*. 1987).

6.7 Accountability

Here lies Douglas-fir, only an infant at the time of its demise. Its heritage was noble, its potential value great; how can it be that death came so soon? Certainly I was not responsible!

A seedling out of its natural element is at risk. The added complications of handling, confinement and exposure can be fatal. When mortality occurs, it's not a matter of "who dun' it", it's a matter of who is willing to accept his share of the blame and take steps to ensure that it does not happen again.

There are two factors that are crucial in an assessment of seedling demise in the field: the appearance of the seedling and the time of death. Stress symptoms appear as delayed flushing, bud abortion, bottlebrush needles, needle chlorosis (yellowing), etc. Seedling death is expressed by red, chlorotic, dull green and brittle, or brown tissues. All red, yellow, or green and brittle seedlings eventually turn brown.

Consequently, the time of death becomes very important in an assessment of the cause. Early, frequent surveys in spring are necessary to establish time of death arising from culture and/or handling problems. Results from an October survey are of little use in determining whether a seedling died from poor handling in May or from drought in August. Plantation evaluation must begin early in the growing season, and the results, good or bad, must be communicated to all involved.

6.8 WHAT CAN I DO?

Numerous operational practices (Table 1) can trigger a stress response. Each stress event plays a part in reducing seedling vigor, particularly if the events occur so frequently that full recovery from any one stress is disallowed. Even if recovery occurs fairly quickly, the consequences of developmental setbacks may influence future response. Make plans to minimize any stresses over which you have control. Then, for Murphy's sake, make contingency plans!

Numerous publications address seedling care and handling (DeYoe 1986). Use the information they contain to establish your own set of guidelines for safe manipulation of stock. You may be able to help those responsible for stock safety to understand seedlings better from a physiological point of view. After all, until we see things differently, we rarely take steps to change our habits.

HOW DO *YOU* PERCEIVE A SEEDLING NOW?

6.9 REFERENCES

Adams, C. and Rinne, R.W. 1982. Stress protein formation: gene expression and environmental interaction with evolutionary significance. Internatl. Rev. Cytol. 79:305-315.

Bazzaz, F.A., Chiariello, N.R., Coley, P.D. and Pitelka, L.F. 1987. Allocating resources to reproduction and defense. BioScience 37: 58-67.

Berridge, M.J. 1987. Inositol triphosphate and diacylglycerol: two interacting second messengers. Annu. Rev. Biochem. 56:159-193.

Bloom, A.J., Chapin, F.S. III and Mooney, H.A. 1985. Resource limitations in plants--an economic analogy. Annu. Rev. Ecol. Syst. 16:363-392.

Boardman, N.K. 1977. Comparative photosynthesis of sun and shade plants. Annu. Rev. Plant Physiol. 23:355-377.

Borowitzka, L.J. 1981. Solute accumulation and regulation of cell water activity. p. 97-130 *In:* L.G. Paleg and D. Aspinall, Ed. Physiology and Biochemistry of Drought Resistance in Plants. Academic Press, New York.

Burke, M.J., Gusta, L.V., Quamme, H.A., Weiser, C.J. and Li, P.H. 1976. Freezing and injury in plants. Annu. Rev. Plant Physiol. 27:507-428.

Caldwell, M.M. 1981. Plant response to solar ultraviolet radiation. p. 57-107 *In:* O.L. Lange, P.S. Noble, C.B. Osmond and H.Ziegler, Ed. Encyclopedia of Plant Physiology. Fol. 12A. Physiological Plant Ecology I. Springer-Verlag, Berlin.

Cech, T.R. 1986. RNA as an enzyme. Sci. Am. 255:64-75.

Chapin, F.S. III, Bloom, A.J., Field, C.B. and Waring, R.H. 1987. Plant responses to multiple environmental factors. BioScience 37:49-56.

Chapman, D. 1975. Phase transitions and fluidity characteristics of lipids and cell membranes. Rev. Biophysiol. 8:185-235.

Colombo, S.J. 1987. Changes in osmotic potential, cell elasticity and turgor relationships of second-year black spruce container seedlings. Can. J. For. Res. 17:365-369.

DeYoe, D.R. 1986. Guidelines for handling seeds and seedlings to ensure vigorous stock. Oreg. State Univ., For. Res. Lab., Corvallis, Oreg. Spec. Publ. 13. 24 p.

DeYoe, D.R. and Brown, G.N. 1979. Glycerolipid and fatty acid changes in eastern white pine chloroplast lamellae during the onset of winter. Plant Physiol. 64:924-929.

DeYoe, D.R. and Drakeford, D.R. 1987. Ethylene, ethane, acetaldehyde and ethanol evolution: indicators of stress during culture and handling. Soc. Am. For. Natl. Conv., Minneapolis, Minn. [Abstract]

DeYoe, D.R. and MacDonald, J. 1987. Culturing strategies that improve bud development and cold hardiness of containerized Douglas-fir seedlings. Symposium on Woody Plant Growth in a Changing Physical and Chemical Environment. IUFRO Section S2.01-11. Univ. B.C., Vancouver. [Abstract]

Dunsworth, B.G. 1987. Quality control field experiment. B.C. Min. For. Lands, Vancouver Region, Vancouver, B.C. Section 88 project, Rep. No. 315.14.

Duryea, M.L., ed 1985a. Evaluating seedling quality: Principles, procedures, and predictive abilities of major tests. Workshop Proc. Oreg. State Univ., For. Res. Lab., Corvallis, Oreg. 143 p.

Duryea, M.L. 1985b. Evaluating seedling quality: Importance to reforestation. p. 1-6 *In:* Evaluating seedling quality: Principles, procedures, and predictive abilities of major tests. Workshop Proc., Oreg. State Univ., For. Res. Lab., Corvallis, Oreg.

Eisenman, G. 1987. An introduction to molecular architecture and permeability of ion channels. Annu. Rev. Biophys. Chem. 16:205-226.

Gale, J. and Zeroni, M. 1985. The cost to plants of different strategies of adaptation to stress and the alleviation of stress by increasing assimilation. Plant and Soil 89:57-67.

Helper, P.K. and Wayne, R.O. 1985. Calcium and plant development. Annu. Rev. Plant Physiol. 36:397-439.

Hewitt, E.J. and Smith, T.A. 1975. Plant mineral nutrition. The English Universities Press Ltd., London. 298 p.

Hoque, E. 1982. Biochemical aspects of stress physiology of plants and some considerations of defense mechanisms in conifers. Eur. J. For. Pathol. 12:280-296.

Ingestad, T. and Lund, A-B. 1986. Theory and techniques for steady state mineral nutrition and growth of plants. Scand. J. For. Res. 1:439-453.

Jaffe, M.J. 1980. Morphogenic responses of plants to mechanical stimuli or stress. BioScience 30:239-342.

Jones, M.M., Turner, N.C. and Osmond, C.B. 1981. Mechanisms of drought resistance. p. 15-37 In: L.G. Paleg and D. Aspinall, eds. Physiology and biochemistry of drought resistance in plants. Academic Press, New York.

Kauppi, P. 1984. Stress, strain, and injury: Scots pine transplants from lifting to acclimation on the planting site. Acta For. Fenn. 185:1-49.

Kim, Y.T., Glerum, C., Stoddary, J. and Colombo, S.J. 1987. Effect of fertilization on free amino acid concentrations in black spruce and jack pine containerized seedlings. Can. J. For. Res. 17:27-30.

Kimmerer, T.W. and Kozlowski, T.T. 1982. Ethylene, ethane, acetaldehyde, and ethanol production by plants under stress. Plant Physiol. 69:840-847.

Kozlowski, T.T. 1979. Tree growth and environment stresses. Univ. Washington Press, Seattle. 192 p.

Kozlowski, T.T. 1984. Flooding and plant growth. Academic Press, New York. 368 p.

Kramer, P.J. and Kozlowski, T.T. 1979. Physiology of woody plants. Academic Press, New York. 811 p.

Kuhlemeir, C., Green, P.J. and Chua, N-H. 1987. Regulation of gene expression in higher plants. Annu. Rev. Plant Physiol. 37:221-258.

Langerud, F.R. and Sandvik, M. 1987. Development of containerized *Picea abies* (L.) Karst. seedlings grown with heavy watering on various peat, perlite and mineral wood mixtures. New. For. 1:88-99.

Larcher, W. 1983. Physiological plant ecology. Springer-Verlag, Berlin. 303p.

Lehninger, A.L. 1982. Principles of biochemistry. Worth Publishers, Inc., New York. 1011p.

Levitt, J. 1980a. Responses of plants to environmental stresses. I. Chilling, freezing, and high temperature stresses. Academic Press. New York. 497 p.

Levitt, J. 1980b. Responses of plants to environmental stresses. II. Water, radiation, salt, and other stresses. Academic Press, New York. 606 p.

Lindstrom, A. 1986. Freezing temperatures in the root zone - effects on growth of containerized *Pinus sylvestris* and *Picea abies* seedlings. Scand. J. For. Res. 1:371-377.

Morgan, J.M. 1984. Osmoregulation and water stress in higher plants. Annu. Rev. Plant Physiol. 35:299-319.

Ninnemann, H. 1980. Blue light photoreceptors. BioScience 30:166-170.

Oquist, G. and Martin, B. 1986. Cold climates. p. 237-293 *In:* N.R. Baker and S.P. Long, eds. Photosynthesis in contrasting environment. Elsevier Science Publ.

Poljakoff-Mayber, A. 1981. Ultrastructural consequences of drought. p. 389-404 In: L.G. Paleg and D. Aspinall, eds. Physiology and biochemistry of drought resistance in plants. Academic Press, New York.

Powles, S.B. 1984. Photoinhibition of photosynthesis induced by visible light. Annu. Rev. Plant Physiol. 35:15-44.

Raison, J.K., Berry, J.A., Armond, P.A. and Pike, C.S. 1981. Membrane properties in relation to the adaptation of plants to temperature stress. p. 261-274 *In:* N.C. Turner and P.J. Kramer, eds. Adaptation of plants to water and higher temperature stress. John Wiley and Sons, New York.

Sachs, M.M. and Tuan-Hua, D.H. 1986. Alteration of gene expression during environmental stress in plants. Annu. Rev. Plant Physiol. 37:363-377.

Sakai, A. and Larcher, W. 1987. Frost survival in plants: responses and adaptation to freezing stress. Springer-Verlag, Berlin. 321 p.

Siminovitch, D. and Cloutier, Y. 1983. Drought and freezing tolerance and adaptation in plants: some evidence of near equivalences. Cryobiology 20:487-503.

Singer, S.J. 1974. The molecular organization of membranes. Annu. Rev. Biochem. 43:805-833.

Smith, H. 1982. Light quality, photoperception, and plant strategy. Annu.Rev. Plant Physiol. 33:481-518.

Smith, F.A. and Raven, J.A. 1979. Intracellular pH and its regulation. Annu. Rev. Plant Physiol. 39:289-311.

Steponkus, P.K. 1984. Role of the plasma membrane in freezing injury and cold acclimation. Annu. Rev. Plant Physiol. 35:543-584.

Tabbush, P.M. 1986. Rough handling, soil temperature, and root development in out planted Sitka spruce and Douglas-fir. Can. J. For. Res. 16:1385-1388.

Tabbush, P.M. 1987. Effect of desiccation on water status and forest performance of bare rooted Sitka spruce and Douglas-fir transplants. Forestry 60:31-43.

Tanford, C. 1961. Physical chemistry of macromolecules. John Wiley and Sons Inc., New York. 710 p.

Teeri, J.A. 1981. Adaptation of kinetic properties of enzymes to temperature variability. p. 251-260 In: N.C. Turner and P.J. Kramer. eds. Adaptation of plants to water and high temperature stress. John Wiley and Sons, New York.

Teskey, R.O. and Hinckley, T.M. 1986. Moisture: Effects of water stress on trees. p. 9-34 *In*: T.C. Hennessey, P.M. Dougherty, S.K. Kossuth. and J.D. Johnson, eds. Stress physiology and forest productivity. Martinus Nijhoff, Boston.

Tinus, R.W. 1986. Relation between cold hardiness, root growth capacity. and bud dormancy in three western conifers. p. 80-87 In: Proc. Combined Western For. Nursery and Intermtn. Nursery Assoc. Meet.. Tumwater, Wash.

Tranquillini, W. 1979. Physiological ecology of the alpine timberline. Springer-Verlag, Berlin. 137 p.

Turner,N.C. and Kramer, P.J. 1981. Adaptation of plants to water and high temperature stress. John Wiley and Sons, New York. 482 p.

Vidaver, W. and Binder, W. 1987. Variable chlorophyll fluorescence:

HANDLING: NURSERY TO THE PLANTING SITE

FROM COMPANY AND DISTRICT PERSPECTIVES

7.0 STOCK HANDLING BY DOMTAR

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7.1 INTRODUCTION

On March 31, 1982, the Ontario Ministry of Natural Resources (OMNR) and Domtar Forest Products of Domtar Inc., signed a Forest Management Agreement (FMA) for the Lake Nipigon Forest. The Lake Nipigon Forest, which is located immediately southeast of Lake Nipigon (Figure 1), is 612,926 hectares in size and supplies Domtar's pulp and paper mill in Red Rock with an annual harvest of approximately 375,000 cubic meters of softwood.

Tree planting operations, as part of Domtar's commitment under the FMA commenced in 1982 with the planting of 100,000 bareroot seedlings. Figure 2 illustrates Domtar's annual planting program since the signing of the FMA. All bareroot stock planted on the Lake Nipigon Forest has been supplied by the OMNR from its Thunder Bay Forest Station. Containerized stock has been supplied by the OMNR from its greenhouse complex at the Thunder Bay Forest Station as well as from each of the six private growers in the Thunder Bay area. The major container stock type has been the Japanese paper pot FH 408, however in 1987, Domtar planted 150,000 jack pine Multipot containers.

The majority of Domtar's tree planting operation is contracted out. However, Domtar is obligated under union agreements to supply tree planting opportunities for regular woods workers who are not employed at their normal job responsibilities.

7.2 Stock handling - General

Previously, Sue Millson mentioned that stock production is just one link in the chain of forest management and I strongly agree with this scenario. I would like to think that stock handling is also one link in

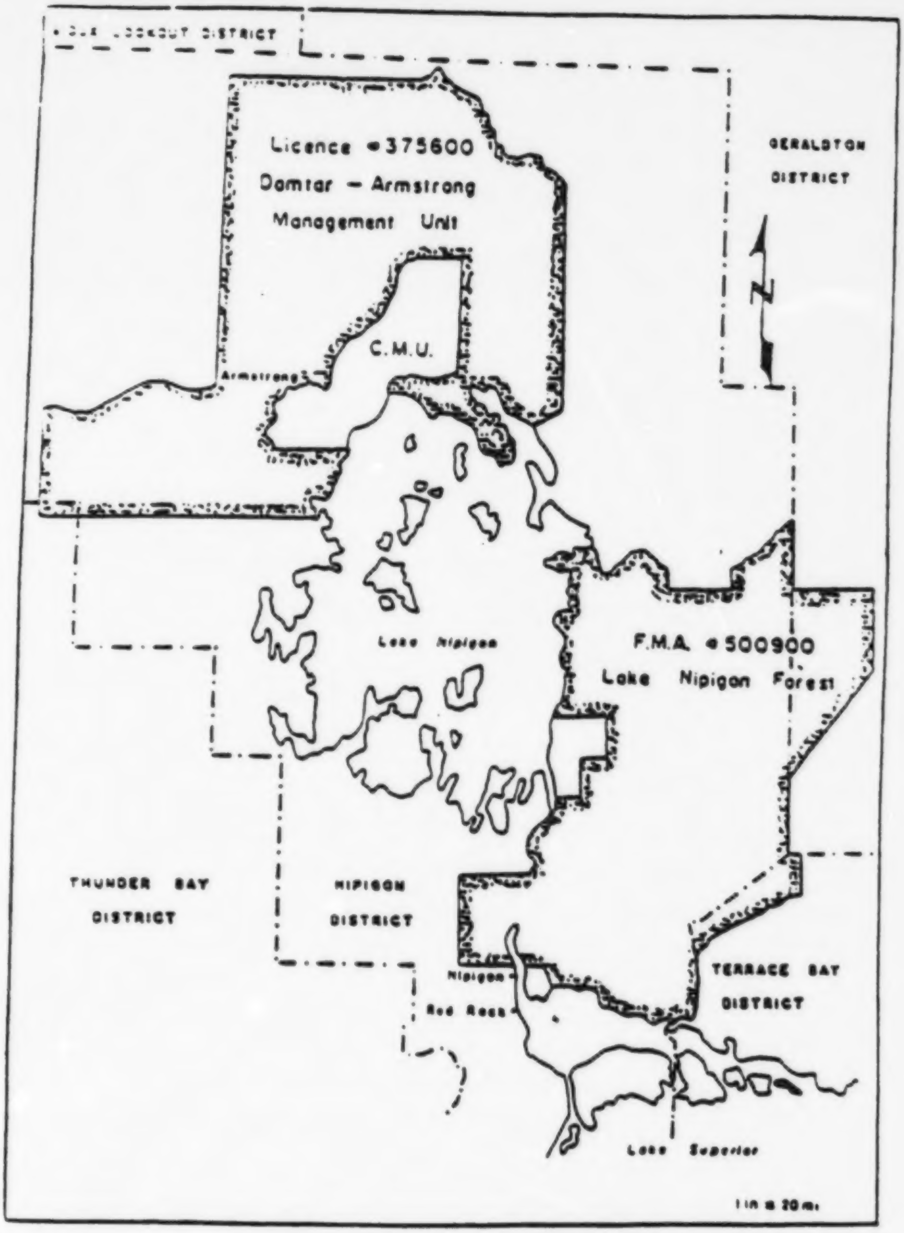
SIOUX LOOKOUT DISTRICT
Licence #375600
Domtar – Armstrong
Management Unit
GERALDTON
DISTRICT
C.M.U.
Armstrong
Lake Nipigon
F.M.A. #500900
Lake Nipigon Forest
THUNDER BAY
DISTRICT
NIPIGON
DISTRICT
Nipigon
Red Rock
TERRACE BAY
DISTRICT
Lake Superior
1 in = 20 mi

Figure 1. Location of the Lake Nipigon Forest.

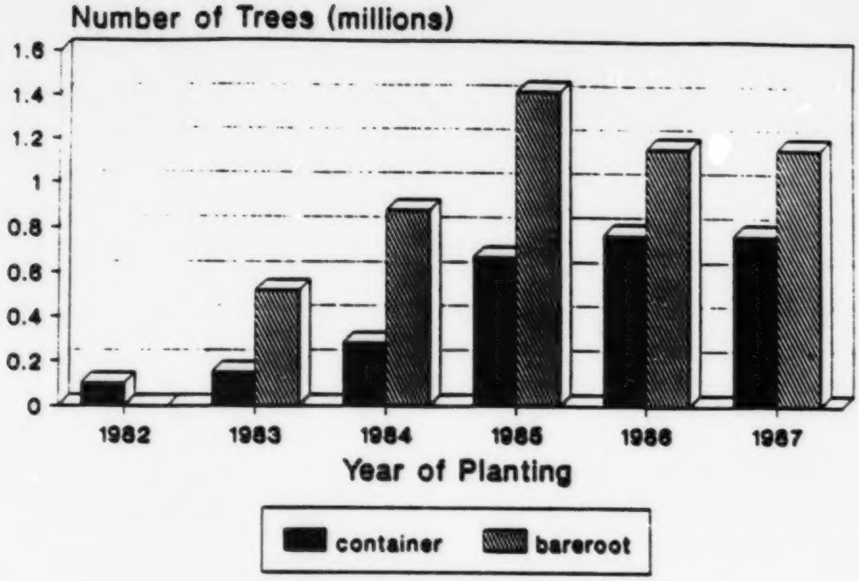

Figure 2. Annual planting program of Domtar Forest Products in the Lake Nipigon Forest from 1982 to 1987.

the chain of events that goes towards our objective of establishing a successful plantation that will reach free-to-grow status (Figure 3). That is our collective objective and we should not lose sight of it during any or all phases of tree planting.

7.3 Stock handling - Bareroot

Initially, Domtar utilized an abandoned mine shaft at Beardmore to store bareroot stock. It soon became evident that this storage arrangement would not accommodate the larger planting program scheduled for 1984. The mine shaft was not central to our planting block and would have resulted in long distance tree delivery to the field. As such, commencing in 1984, Domtar utilized an OMNR refrigerated van as a central storage unit. A full van would be dropped off and the truck would return with the empty van. The trees were not stored right at the planting site and ideal storage temperatures and relative humidities could be maintained.

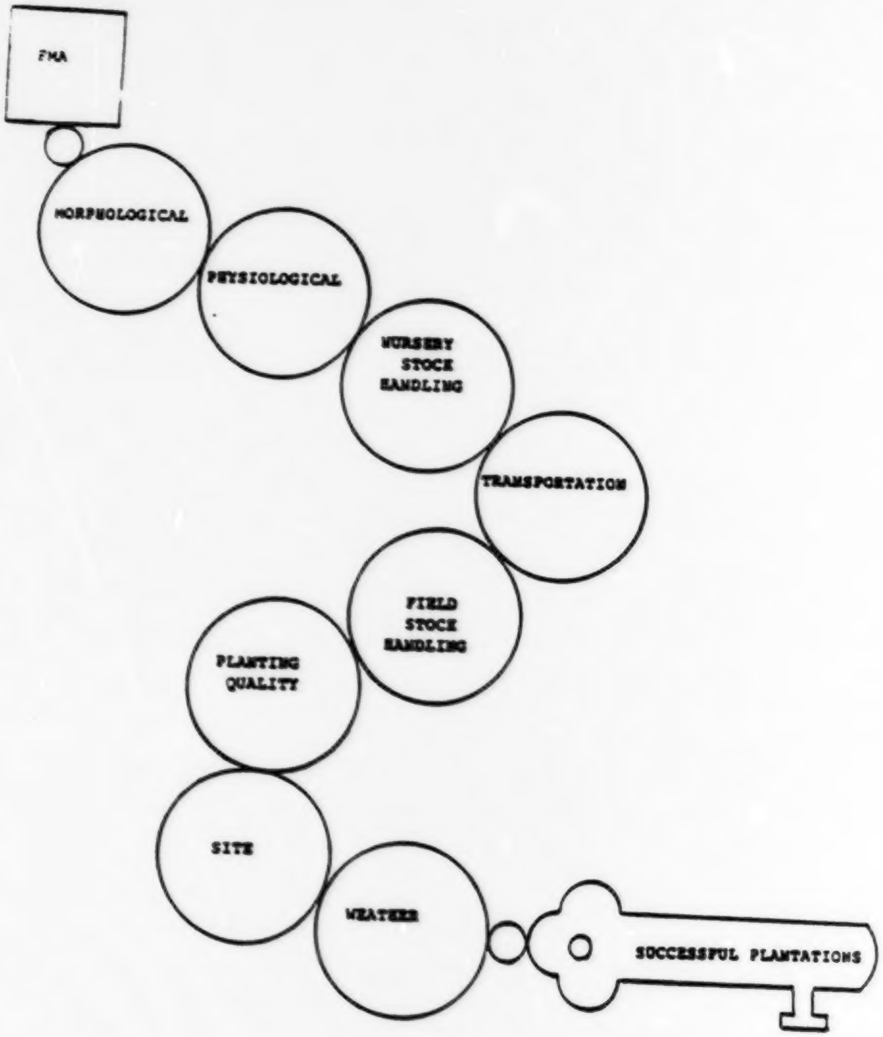
FMA
MORPHOLOGICAL
PHYSIOLOGICAL
NURSERY STOCK HANDLING
TRANSPORTATION
FIELD STOCK HANDLING
PLANTING QUALITY
SITE
WEATHER
SUCCESSFUL PLANTATIONS

Figure 3. *Key chain* to successful plantations.

The trees are removed from the "reefer" and transported to the actual planting site where they are disseminated to the planters. There is never more than one day's trees on the site at any given time. Trees at the planting site are kept in the shade and covered with reflective tarps.

Prior to planting, the trees are dumped out of the boxes and the roots dipped into water. The trees are then stacked upright in the boxes, which are lined with the original plastic bag to retain the moisture. A pail of water usually is poured in the box so the roots are able to soak up as much water as required. The boxes of dipped trees are then transported directly to the individual planter's block put under some form of shade. They are usually transported to the blocks by half-ton, but in some inaccessible blocks, an all-terrain type of vehicle is utilized.

To date, Domtar has required the Contractor to dip and soak the roots in water at least four hours before planting. This is specified right in the Tree Planting Contract. In most cases, the Contractor will set out trees the night before so the planters can get started first thing in the morning. Those trees may be left soaking for twelve hours or more. Based on discussions at this workshop, Domtar will be re-assessing its root soaking procedures.

Planters fill up their planting bags at the roadside and may separate trees within bundles prior to packing. Domtar ensures that the trees are not jammed into the bag. There is no unauthorized root pruning and all trees not in the process of being planted must be watered and kept in the shade.

In 1987, Domtar, in an effort to assist the OMNR to alleviate overwintered storage problems, constructed a snow cache of 100,000 black spruce 1-1/2 - 1-1/2 bareroot stock. It was easy to divert a load of sawdust destined to our mill in Red Rock and utilize an idle gravel loader to construct a snow cache in four to five hours. Domtar acknowledges advice from the OMNR, Thunder Bay District Office.

The best feature of a snow cache is "what goes in is what comes out". Snow caches help alleviate some of the recent problems the Thunder Bay Forest Station has had with winter desiccation because of insufficient snow cover in the nursery beds. There was concern about flexibility and how long a snow cache can be maintained? These concerns were tested in 1987 as one of the planting blocks, which had a high clay content, was not available during the initial plant due to a very dry spring. With daily monitoring and some cosmetic repair to the sawdust layer, the snow cache was maintained almost to the end of May when conditions improved, allowing the block to be planted. Domtar was not able to obtain any fall-lifted stock in order to establish a snow cache for the 1988 planting season.

7.4 Stock handling - Container

Container stock for the Lake Nipigon Forest is delivered by the OMNR in non-refrigerated transport trucks. The paper pot trays are placed into large black plastic tubs which then allow the trays to be stacked for transportation. Trees are manually unloaded one tube at a time utilizing rollers. Stjernberg (1988) indicates that between 2.76 and 6.33 manhours is required to unload 100,000 paper pot seedlings. Unloading seedlings at the cache is one area where improvements can be made to increase productivity.

The trays are placed on a flat, well-drained site that is easily accessible and in close proximity to a good supply of water. The trees are monitored daily and watered with a fire pump and a mist/fogger nozzle either early morning or late evening. In most cases, these trees are planted within three to five days after delivery.

If the trees are to be stored more than one week, they may be stored in a moist, dense black spruce stand in an effort to reduce transpiration and lessen the frequency of watering.

Container seedlings are transported to the planting blocks in half-ton trucks equipped with a rack constructed specifically for container stock movement. In some remote areas, an all-terrain vehicle (ATV) has been utilized.

The planters fill up their rigid bottom planting bags or kidney trays at the roadside. At that time, they separate the paper pot containers and cull all blank cavities and trees less than minimum size.

If the OMNR elects to adopt a containerless seedling, they must ensure that growing regimes are designed to produce a seedling that has a root plug that is able to retain the growing medium through all the rigours of operational planting.

7.5 Conclusions

Domtar's method of stock handling does not differ significantly from any other planting projects in Northwestern Ontario. It is up to the growers to produce a seedling that meets morphological, as well as physiological parameters that are negotiated between the grower and the forest manager. It is then up to the field staff to understand and minimize the stress factors outlined during these proceedings so that a successful plantation can be established and our objectives can be achieved.

7.6 REFERENCES

Stjernbert, E.I. 1988. A study of manual tree planting operations in central and eastern Canada. For. Eng. Res. Inst. Can., Pointe Claire, Quebec. FERIC Tech Rep. No. TR-79, 42 p.

8.0 DISTRICT HANDLING PROCEDURES: SIOUX LOOKOUT

Neale Waters, Forest Technician
Ontario Ministry of Natural Resources
Sioux Lookout District

8.1 INTRODUCTION

The tree planting program in the Sioux Lookout District is very dynamic, with approximately 1.8 million trees being planted annually. Jack pine and black spruce are the primary species planted in the district, but occasionally white spruce, red pine and exotic species are also planted. The planting program in Sioux Lookout usually spans from the end of April to the end of July with all planting now being carried out by private planting Contractors. The magnitude of our reforestation program and the district approach to planting have enabled staff to become quite adept with the proper stock handling techniques for both bareroot and container seedlings.

8.2 Bareroot stock

Last year's early spring resulted in the local curling club being used as a temporary storage facility for all our bareroot stock. When storing stock, care is taken in handling bags to ensure they are not piled on top of one another. In this circumstance, the trees were raised off the ice with 5 cm x 10 cm boards and the doors were opened at night to let in the cool air. The stock was transferred by hand to the storage facility and stored this way for approximately two weeks. This situation was very unusual and labour intensive.

Usually, bareroot stock is delivered from the Dryden Tree Nursery on a predetermined delivery schedule which coincides with the arrival date of the planting Contractor. Stock is transported directly from the Nursery to the planting site and kept in refrigerated vans (reefers), in a central location. This facilitates the delivery and pick-up of trees by the Contractor. Temperature in the reefers is set at $+2^{0}$ C, but is maintained between $+2^{0}$ C and $+5^{0}$ C at all times. Two to three thermometers are placed inside the reefer, in strategic locations, in order to monitor the daily temperatures. A seven-day thermometer on the reefer records, in chart form, the weekly temperature fluctuations. This chart is monitored daily as trees are removed from the reefer for planting and when the cooling system is being serviced.

Pick-up of stock is limited to twice daily, once in the early morning and once in the early afternoon. This procedure limits the number of times the doors are opened which keeps the temperature fluctuations to a minimum, allowing us to stabilize temperatures more readily.

Reefers are kept locked at all times, except when the Contractor is being issued stock by Ministry staff. A daily log of trees signed out to the Contractor is recorded on "Van Sales Slips". These records enable us to keep an inventory of the seedlings, so that we are able to request additional stock shipments from the Nursery as required. The daily quantity of stock signed out to the Contractor is kept in sync with his planting rate. This eliminates the potential for large numbers of trees being left in field storage overnight. Trees are unloaded along the roadside adjacent to the planting site and placed in tubs (or puddles). In this manner, bareroot stock is conditioned or acclimated at ambient temperatures, with their roots in water, for approximately 4 to 6 hours prior to planting. Trees that are left in field storage overnight, are the first to be planted the following day.

At the outset of the planting project, bundles of trees are counted to determine if there are 25 trees per bundle and the correct number of bundles per bag. This check system consists of randomly sampling 4 - 5 bags per shipment, of which 5 - 10 bundles per bag are counted. Through a combined effort between the Crown and the Contractor, an agreement is reached regarding the number of trees per bundle and trees per bag. On the plant, Contractors are urged to adhere to Schedule 'C' of the Tree Planting Agreement when handling nursery stock and are reminded when contravention occurs. Schedule 'C' refers to storage and handling of nursery stock.

Planters are required to remove one bundle of trees at a time, untie it, separate the stock and return it to their planting bags. Seedlings are removed one at a time for planting. This procedure reduces the chances of stock damage and root desiccation, and minimizes the chances of accidentally dropping trees. Periodic checks are conducted by Ministry staff to ensure that planters' bags have adequate water or sufficient packing material that will keep seedling roots moist. Bareroot stock are planted before container stock. This way, all bareroot stock is planted prior to flushing; keeping the storage time to a minimum and saving money on reefer costs.

8.3 Container stock

Container stock is also delivered from the Nursery on a predetermined delivery schedule and transported directly to the planting sites.

Our District has a 30 m x 32 m free standing shade house, equipped with a perforated 73% shade cloth, which can accommodate approximately 300,000 seedlings. When purchased, we had the choice of a few types of shade cloth (50%, 73%, and 90%). The 73% cloth was chosen because we felt that the 90% cloth would provide too much shade and that the 50% cloth would not provide enough shade and would allow too much wind through. The cost of this shade house was approximately $5 000.

The shade house has eliminated the need to water seedlings everyday, even on the hottest days. Except for the more exposed rows at the ends, which are watered as required, seedlings need only be watered every 2 - 3 days. Watering in the shade house can be carried out any time of the day, but we prefer to water in the early morning.

The structure of the shade house allows for complete portability so that it can be constructed on almost any site. A trailer which can accommodate 10 m lengths of pipe is required to transport the unit. Unfortunately, this unit can usually only hold enough stock for one (maybe two) planting projects. Consequently, if more than one planting project is running at one time, some container stock will have to be stored outside.

Field storage sites for container stock are centrally located within the planting areas in order to reduce the distance the stock has to travel over rough roads, and reduce the chance of damage during transport from storage to the planting area. Field storage sites are carefully located on relatively flat ground, protected from wind and large enough to accommodate the number of trees that are going to be stored. Storage sites must also be close to a water source. If trees are to be stored longer than 4 or 5 days, they are raised off the ground with 5 cm x 10 cm boards. This technique has the advantage of:

1) stopping the roots from growing into the ground, preventing damage when lifting for shipment to the planting site,
2) promoting uniform drying of stock, and
3) helping to heat up the plugs, inducing active growth.

Trees stored in the field are watered, depending on the weather, usually everyday. To determine the seedlings' watering needs, the plug moisture is monitored daily by random sampling of stock throughout the storage site. The customary technique is to squeeze the plug by hand; if moisture can't be squeezed out, the seedlings require watering. Seedlings are usually watered early in the morning, allowing the moisture to soak into the plug. Midday watering is avoided since the rapid evaporation of water from the foliage is potentially harmful to the seedlings. Similarly, watering in the evening is avoided because moisture remains on the foliage for a long period of time, possibly creating an attractive environment for certain fungi.

A Wajax Mark 3 fire pump, run at idle and equipped with a fog nozzle, is used to administer a fine spray of moisture, sufficient to fully saturate the plugs. Another system used, when there is a shortage of time or manpower, consists of a series of small sprinklers mounted on 2' posts set up throughout the storage site. When connected to a fire pump, these sprinklers can water approximately 300 000 seedlings and be left unattended for the usual time required to water the seedlings (2-3 hours), or longer. These systems, which use low water pressure, decrease the risk of seedling breakage and increase the likelihood of even coverage of water.

Contractors and planters are instructed, by Ministry staff, about the proper stock handling techniques at the start of the planting project. It is required that seedlings be kept in the Spencer-Lemaire booklets while in the planting bags since this was found to be the best way to prevent over-packing of bags. This technique has also helped to:

1) reduce the chances of damage to terminal shoots of seedlings,
2) keep the root-soil mass intact, and

3) prevent exposure of plugs to air and root desiccation.

Planters are required to remove only one container seedling at a time from their bags for planting, an action which also reduces the exposure of the plug to air. Ministry staff are on location for the duration of the plant to ensure that proper techniques are followed.

8.4 Conclusions

Our staff are very conscious of proper stock handling techniques and this is stressed to the Contractors who work for us. Any concerns regarding stock handling are discussed at our pre-plant meetings with the Contractor. Several techniques are discouraged:

1) pushing plugs or roots of bareroot stock into the planting hole with the shovel;
2) firming up the freshly planted seedling with your heel, which may damage the roots and the tree stem; and
3) leaving stock in the planting bags overnight.

Also, field demonstrations of stock handling and planting techniques are put on for the planters before the outset of the plant. There are usually a few problems at the start of the plant, but these are soon solved and the plant runs relatively smooth thereafter.

9.0 DISTRICT HANDLING PROCEDURES: RED LAKE

Dan Pyke, Unit Forester
Ontario Ministry of Natural Resources
Ignace District

9.1 INTRODUCTION

- Red Lake District is located in the Northwestern Region, approximately 100 miles north of the Trans Canada Highway (Figure 1).
- Red Lake draws stock from two Nurseries primarily:
  (i) MNR Tree Nursery, Dryden for bareroot
  (ii) Wellaire Nursery, Ear Falls, for container stock.
- Other Nurseries available in the Region that are available to obtain stock from are located in:
  : Dryden: Cooks, Evergreen, Tamarack
  : Vermillion Bay: Dutchmill
  : Whitedog: Whitedog
  : Fort Frances: Mutz, Northwest
- Red Lake has traditionally planted large numbers of trees (Table 1).
- Since 1984, when the Pakwash FMA was signed with Boise Cascade, Kenora and the Trout Lake FMA with Great Lakes Forest Products approximately 21,700,000 trees have been planted and considerable experience has been attained in all aspects of tree planting.
- It is evident by this number that this district has had a lot of experience in tree planting.

Table 1. Summary of the numbers of trees planted in the District of Red Lake for 1984 - 1987 by operating unit.

RED LAKE CROWN MANAGEMENT UNIT	5,100,000
PAKWASH FOREST F.M.A.	5,700,000
TROUT LAKE FOREST F.M.A.	10,900,000
TOTAL	21,700,000

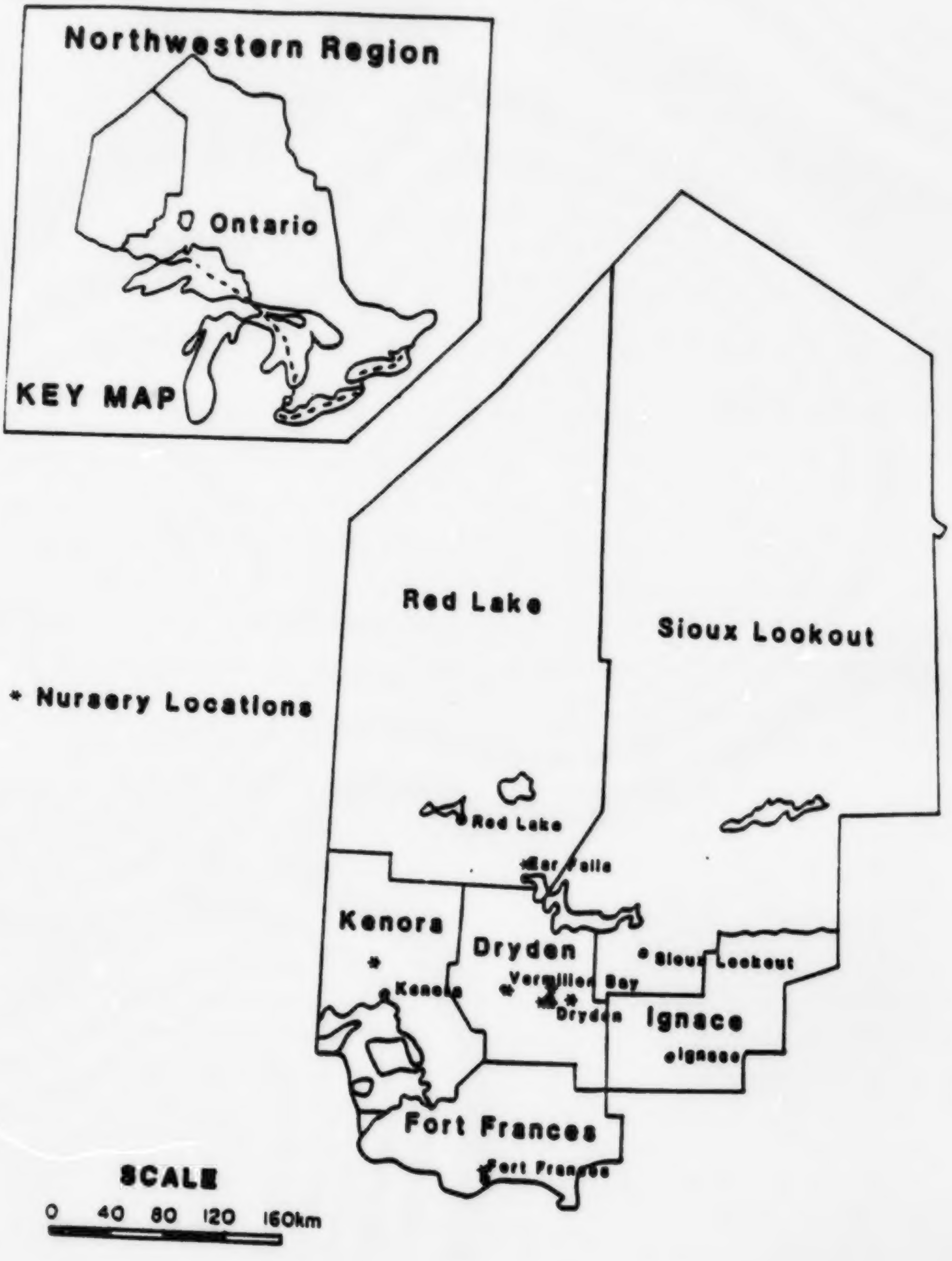
Northwestern Region
Ontario
KEY MAP
Red Lake
Sioux Lookout
* Nursery Locations
Red Lake
Ear Falls
Kenora
Dryden
Kenora
Vermilion Bay
Dryden
Sioux Lookout
Ignace
Ignace
Fort Frances
Fort Frances
SCALE
0 40 80 120 160km

Figure 1. Regional and District setting of Red Lake.

9.2 BAREROOT HANDLING

- There are similarities between all Forest Management Units (similarities and differences are discussed below) in the handling of bareroot stock but some differences do exist.

9.2.1 COMMON HANDLING TECHNIQUES

- All bareroot stock is loaded into refrigerated vans (reefers) at Dryden Tree Nursery for transport to field storage locations.
- Stock is delivered by reefer to the site.
- Stock is transferred by hand into the storage facility (for FMA's).
- Reefers have 1 or 2 levels of shelving.
- Reefer are maintained at 2 degrees celsius.
- Snow caches are being used this year due to a shortage of storage facilities at the nursery.
- Culvert cache uses a 6' culvert, 18' long with pallets on the bottom.
- Trees are stacked 3 bags high.
- Ends are covered with wood and 2-3' of snow piled on top and around, with another 10' of sawdust on top of that.
- Regular cache is similar except no rigid overhead protection is provided.
- Caches are oriented in N-S direction with the north side to be opened first.
- Stock is transferred, by hand, into 1/2 tons or ATV's with trailers and transported to the planting site.
- Bags are unloaded along the roadside adjacent to the planting site.
- Planters open the bags and transfer the stock directly to their planting bags.
- Bags have water or some type of packing material that will keep the roots moist.
- The planters remove one bundle, untie it, separate the stock and return it to their bags.
- Stock is then removed one at a time.

9.2.2 Differences between crown and FMA holders(s)

- Some differences in approach exist between the FMA's and the Crown, although, the basic principles remain the same.
- Having reviewed the procedures employed by companies, the following

differences were noted:

CROWN

- Includes provision for "heeling-in" of nursery stock when requested.
- Nursery stock must be root soaked for no longer than 12 hours.
- No root-pruning of stock.
- Heel-in or return unplanted stock to containers at the day's end.
- Reference to snow caches.
- Stock will be thawed in shipping containers for 24 hours prior to soaking, out of direct sunlight.
- Stock must be dipped immediately after the container is opened, regardless if the stock is to be planted immediately or not.
- Only open the cache as far as is required to access one days worth of planting stock.

FMA HOLDERS

- Tree planters must ensure the roots of all trees are in contact with water or moist packing material.

9.3 Container stock

9.3.1 Common handling techniques

- The Crown delivers all container stock to FMA and Crown Plants.
- Stock (Spencer-Lemaire) is loaded at the Nursery into carrying racks which in turn are loaded onto a flat deck trailer.
- Carrying racks are steel frame with removable plywood ends for loading and unloading the container racks.
- They are transported to the storage site.
- At the storage site, racks are removed from the carrying racks and distributed on the ground.
- Storage sites are typically large areas capable of handling a large number of trees.
- These areas constitute the central storage location.
- Sites must be close to water.
- Stock is watered as required (usually morning, evening).
- Need is determined by random sampling envelopes and checking individual plugs for moisture (usually squeeze in hand).
- Watering is done with a fine spray from a fog nozzle or sprinkler system.

- The Planting Contractor obtains stock from these locations, as needed.
- Stock is loaded usually in 1/2 tons with or without carrying racks.
- Stock is not covered but transported in open air to the planting site (not usually far).
- Stock is unloaded by hand at various strategic locations for accessibility by planters.
- Watering here is the responsibility of the Contractor.
- If stock requires water, back pack pumps are usually used.
- Planters remove envelopes from trays, separate the plugs and put them into planting bags, upright.
- The contract stipulated that the bags must not be overfilled.
- Usually water or packing material is used in the bottom of the bag to keep the plugs moist.
- The planters draw trees out one at a time.

9.3.2 Differences between crown and FMA holders(s)

- One FMA holder developed a main cache location capable of holding 500.0 M trees.
- Have an automatic sprinkler system in place with timer.

9.4 Suggestions for improvement and limitation to implementation

9.4.1 Bareroot - Suggestions

(i) rigid containers be used - better protection of stock in handling, stacking easier and safer.

(ii) Avoid extra handling - FMA holders should receive stock at Nursery in their reefers and transport to their storage locations.

9.4.2 Limitations

(i) rigid containers - expensive relative to bags
- require more handling at nursery
- take up more room

(ii) Extra handling - FMA not explicit as to who has responsibility of handling stock to storage location - extra cost to FMA holder in reefer rentals and transport.

9.4.3 Container Stock - Suggestions

(i) Planting bags be developed for container stock - shorter bags with baffles that would accommodate 1 envelope each. This would reduce plug damage in planting bag.

(ii) Sturdier stock with less succulent tops (esp. Pj) - less fragile and less susceptible to breakage in handling.

(iii) Avoid putting water in the bottom of bags.

9.4.5 Limitations

(i) None - Could be developed and field tested to determine suitability. Problem is that the bag would become specialized only for C/S, therefore more cost to Contractor.

(ii) Nursery culturing technology; private grower's contracts specify certain minimum heights; FMA stock specifications.

(iii) None

9.5 Suggested research needs

1. Bags of trees have a tendency to get thrown around. Aside from the obvious effects of mechanical damage, is there any effect biologically?
2. Root soaking and watering is usually done with water at hand and may or may not be well oxygenated, running water. What is the effect of root soaking in stagnant water? How long should we soak trees? Do we need to soak trees?
3. Does the time of day have any effect on when trees should be watered?
4. In container stock, roots have a tendency to grow out of the bottom of the envelope and grow together, especially if stored on-site for extended periods. Can this be minimized?
5. Does our present method of handling stock significantly impede growth and survival of stock or should we be concentrating our efforts elsewhere?

9.6 CONCLUSIONS

- Systems presently being used seem to work quite well.
- Crown and FMA holders are concerned with handling and have inserted into contracts specifications to ensure stock is handled properly to minimize damage.
- Identified some areas where improvement could be made, research needs/technology transfer.
- All would agree that the less handling the better.

ANOTHER ALTERNATIVE FOR REFORESTATION

10.0 AREA BASED PLANTING

Dave Lehane, Area Forester
British Columbia Forest Products Limited
MacKenzie, B.C.

When I first found out I would be speaking to you I was told that the organizing committee wanted an expert on area based planting. Well, by no means do I profess to be an expert, on the contrary, what I am is a hands-on dirt forester who, like many of you, will be heading into the field next month to administer a planting contract. Probably the only significant difference is that your planters will be paid by the tree while mine are paid by the hectare. The company that I work for began planting in the Mackenzie area in 1972 with a modest 150,000 tree program. We currently harvest 4,500 hectares annually and plant 4.5 million trees on approximately 88% of all areas harvested. From the time our planting programs began in 1972 to the present, stock allocations have fallen short of our needs. Consequently, planting stock is a very valuable commodity. Not only does it represent a direct growing cost of 11 to 32 cents per seedling but there are opportunity costs attributed to plantations forgone through shortages in supply.

As you are probably aware, new forest policy and regulations have been enacted in British Columbia during the last few months. This new legislation makes all reforestation and seedling costs the direct responsibility of the licensee. Since forest companies are now required to provide their own planting stock, restricted seedling supplies limited by Ministry of Forests allocations will no longer be a problem. However, cost effective silvicultural practices will receive even more attention with forestry budgets being closely scrutinized. Any savings in reforestation costs will now accrue directly to the company.

To promote more cost effective plantation establishment and ensure that we plant the maximum area possible with a limited seedling supply, we began to investigate alternatives that could reduce excess planting, tight spacing, and wastage in general. Area based contracts, where the

Contractor is paid based on the number of hectares satisfactorily stocked, was one of these alternatives. We did not instantly switch our entire 4.5 million tree program from the standard tree based payment system to area based, nor was the area based concept an original idea. In fact, I was first introduced to the concept by a planting Contractor who once asked me "Why don't you pay me to do a good job and produce a plantation that everybody will be happy with instead of just paying me to make trees disappear?"

Before I go any further, let's talk about wastage or "stashing" for a moment. Most will admit that it does occur to some extent but no one can be exactly certain what the numbers really are. We have caught Contractors stashing on a large scale and individual planters on a smaller scale. Some of the most reputable planting Contractors in B.C. have told me that they know it happens, but have difficulty controlling it, even when the penalty is immediate firing. Reputable, professional Contractors worry that the indiscretion of one planter may tarnish their hard-earned good names.

It should be clear that area based planting payment effectively eliminates any motive to stash trees.

We first tried area based planting in 1984 with a 750 hectare program. This was increased to 70% of our program in 1985 and our entire program has been planted under area based contracts since 1986. The transition to area based contracts was not without its problems but the bottom line has been worth it. We are presently getting 10 - 15% more area planted with the same number of seedlings when compared to the tree based payment system. This additional area planted equates to a direct savings in seedling costs of close to $100,000 per year.

The benefits from area planting payment can largely be attributed to the different philosophies of the two planting methods. The piecemeal tree based payment system promotes high production planting at the lowest possible per tree cost. There is no incentive for the planter to search out the best microsite nor avoid the poor ones. Planters maximize their profits by slamming in as many trees as possible, not always finding the best spots. We like to call this "paving". Experienced planters are rewarded financially by planting dense on the easiest ground, avoiding difficult areas and pushing trees onto marginal planting sites. Surprisingly naturals only seem to occur on the same side as the planters blind eye. In short the planter must maximize the number of trees he plants and minimize the amount of ground he covers. This often results in overstocking and poor spot selection.

Quality control efforts by Contract Supervisors are then directed at lowering planting density, honouring naturals and striving for better spot selection. The quality control efforts of Contract Supervisors and the ability of planters to maximize profit are in direct conflict.

In area based planting, the planter will maximize his income by maximizing the area planted with a given number of seedlings while staying above the minimum allowable stocking density. It is now in the planters best interest to respect established buffers alongside roads, landings, and cut banks. It has been our experience that once the concept is clearly understood planters will search out the best possible microsites as there is no reward for planting that extra "sleazy" tree. The planter can now maximize his income by working smarter and not by simply slamming in more trees. Partial stocking and naturals are viewed as a bonus rather than a hindrance to production. Ultimately, planters and foresters begin to share the same objectives.

Area based planting can be applied on any planting site. The benefits do however escalate in proportion to the difficulty of the planting site. The most dramatic results occur on sites where planting spots are few or unevenly distributed or where natural regeneration or partial stocking exists.

The problems of monitoring the number of trees planted are removed under an area based system. The total number of trees issued, the number of trees in a box, tray or reefer and even the number of trees an individual planted all become somewhat irrelevant. What is important is the total number of hectares planted. Quality control efforts centre on ensuring that minimum stocking densities are met.

We have found that field administration is simpler for the company and tree utilization becomes more efficient, less wasteful. The overall result of using area based payment is the ability to stock more area with a fixed number of trees.

As I mentioned earlier the transition to area based planting was not without its rough spots. Just as the system requires a conceptual change for the planter an equal change is required from company supervisors and foresters. During our first season, we found that our checkers were accepting stocking levels far below the prescribed minimum. Checkers now faced the new challenge of ensuring that all available planting spots were filled and the unit was not underplanted as opposed to traditionally guarding against overplanting and wastage.

From the foresters perspective, more detailed site prescriptions were required regarding distribution of acceptable naturals and plantable spots. The budgeting process changes slightly from having a fixed number of trees and a fixed contract value to having a variable number of hectares and not knowing the exact contract value until all planting is complete.

To achieve the maximum benefits from the area payment system a detailed pre-work conference is required to communicate the foresters objectives directly to the individual planters. Definitions of plantable spots and acceptable naturals may vary from site to site depending on species or soil type and these definitions must be clearly understood by the Contractor and planter before the first planter leaves the tree cache.

The pre-work conference is important on any silviculture contract. Its importance is however magnified when planters are expected to adapt to a new payment system. For planters to be fully motivated, they must be convinced of the merits of the new administrative system and fully understand the monitoring policy.

Even though our planting contract is over 20 pages long, the meat of it is straight forward and simple. Once you have waded through the whereas and wherefor's, which must be included to provide job security for the legal profession, you will find two very important items: Minimum Acceptable Stocking Levels and Minimum Acceptable Quality.

At present, our target stocking is 1,100 trees per hectare. It doesn't matter if your stocking level is 1100 or 2400 trees per hectare when planters are paid by the hectare and, human nature being what it is, there are strong possibilities of receiving a product at something less than desired stocking. To alleviate this potential problem, our contract clearly specifies that if planting densities fall more than 5% from the target stocking, there will be no payment. Simply put, we want 1,100 TPH; if we get less than 1,050 including naturals, the Contractor has one opportunity to replant or he receives no payment for the unit.

Under tree based planting, quality is a function of the number of trees planted, plantable spots, planting density and excess, all closely tied to a broad set of tolerances. With area based payment, spacing, density and excess are naturally regulated by the planters instinct to maximize income. Quality need only be calculated by dividing the number of well planted trees by the total number of trees planted. In our case, there is no formula for partial payment. Quality of 93% or greater receives 100% payment, lower quality receives no payment. As harsh as these quality and density specifications may appear, most of our Contractors prefer them as the ground rules are clearly set and the games of juggling quality and excess are removed.

Areas can be calculated using a closed traverse with hipchain and compass. This method is practical and probably the best solution on small or part blocks but it is time consuming and costly on larger units. At present, our contracts are paid by areas derived from 1:10,000 scale maps produced from high elevation aerial photographs. Unplantable areas including roads, landings, swamps and buffers are deleted to arrive at the net payment area.

As part of our current logging program 1:40,000 scale aerial photos are flown and 1:10,000 scale logging history maps are updated annually. The total cost of less than $1.75 per hectare is of only minor significance when weighed against the importance of accurate area reconciliation for site preparation, planting and other silvicultural applications.

When you are forced to utilize old base maps or air-photos, discrepancies in area are likely to occur and it is important that company and Contractor acknowledge they exist and come to some equitable agreement.

In addition to knowing the total block area, it is important that the Contractor keep track of the area planted by individual planters. To this end, Contractors will normally traverse the blocks to be planted subdividing them into smaller 3 to 10 hectare units. Once surveyed, individual or small groups of planters are assigned to each unit. Individual planters can then relate their daily production to area planted and daily income. Since there is usually only one or two planters assigned to each unit, the planter is directly responsible for his own planting quality and density. This provides a greater incentive to the individual to maintain good quality and increases job satisfaction. Good and poor planters become easily recognizable as they are no longer protected by the average.

The costs of traversing are significantly reduced when accurate base maps are provided and all that is required is to connect tie points. Traversing costs currently average between 3 and 7 dollars per hectare and are born solely by the Contractor.

Since subdividing of planting units is a direct cost to the Contractor, he may attempt to pay his planters on a pro-rated basis instead of traversing. This should be vigorously discouraged as basing individual planter payments on the proportion of seedlings he plants defeats the purposes and negates the benefits of area planting.

As with any new system, there will be a break-in period. Initially, we have found that planters experience frustration at not knowing their exact daily earnings. This early frustration can be partially alleviated by traversing the first blocks planted into smaller units. Generally, we have found it takes 3 to 5 days before planters become comfortable and start thinking area and not pennies per tree.

When initially making the transition to area base, the unit price paid to the planter may be difficult for the Contractor to evaluate. Until your Contractors become comfortable with the area based system, I suggest that the usual tree price multiplied by your minimum stocking is a good place to start. As your Contractors become more familiar with the system and competitive, the bid prices per hectare should drop as the benefits of area based contracts begin to accrue to both Contractor and company.

I recently had the opportunity to renegotiate a contract, changing it from tree base to area base. The contract had already been awarded and signed so the Contractor was under no obligation to strike any compromises. This particular Contractor has planted area based for several years and is convinced of the system's merits. As a result, we were able to renegotiate the contract, at the tree price multiplied by the minimum density, and then deduct 5% to come up with a final contract price per hectare we were both very comfortable with.

Theoretically, with proper contract language, wage structure and diligent supervision, there should be no difference between the plantations established under tree based or area based payment systems. Indeed the most common reason people give me for not trying area based planting is that they can get just as good a job with the traditional tree based contract. This may very well be true and I am not suggesting that area based planting is a panacea. However, during the past four years, we have planted over 13,000 hectares using area based payment and attribute some significant benefits directly to it. We have experienced:

- markedly lower seedling wastage
- improved recognition of acceptable naturals as potential crop trees
- improved microsite selection
- absence of tight spacing on easier ground
- 10 - 15% more area planted with a fixed seedling supply
- simplified field administration as Contractor and company share similar objectives

These are some of the advantages that we attribute to an administrative system that we are obviously very happy with. I encourage you to experiment with area based planting and be your own judge. I also caution you to give it an honest trial and expect growing pains. Remember that any benefits will be diluted if you let your Contractor pay his employees on a pro-rated basis. The success of area based planting requires an attitude change and a break-in period to avoid mixing area based and tree based payment on the same contract.

Work closely with your Contractor and utilize his ingenuity. Remember that the benefits of the area based system are maximized when the Contractor, planter and forester share the same objectives.

11.0 SUMMARY REMARKS[1]

Dr. Dave R. DeYoe, Seedling Physiologist
MacMillan Bloedel Limited
Land Use Planning Advisory Team
Woodlands Services Division
Nanaimo, British Columbia

For the past two days I have been a participant from the standpoint of a speaker as well as a member of the audience. In doing so, I have listened to broad problem statements and descriptive methods on how some of these problems associated with regeneration are dealt with. Solutions are often straight forward and based in common sense; others however, are dealt with in rather novel or innovative ways. What comes clearly to my mind is that there appears to be an abundance of expertise in this Province to solve problems that you may have now or that will occur in the future.

Awareness is an important starting point in the resolution of any problem. Technology development units can provide awareness to respective clients through communication forums such as this meeting. What were we made aware of at this meeting? First and foremost, I would say that the delicate nature of nursery seedlings is now imprinted on our minds and that seedlings are sensitive to all forms of stresses. We measure certain attributes of seedlings with the hope of obtaining some valuable information on present health or on future performance but generally, our measured attributes do not appear to be sensitive enough to elicit a response. We must move away from measuring everything and assess what is best to measure to meet our specific objectives and determine what technology is available to do it.

In the past, we have extrapolated and implemented information and techniques without a sufficient data base or thorough listing. Extrapolation and implementation must stop because blunders can be made and inappropriate practices can be initiated, taking many years to resolve e.g. root soaking. Long term monitoring and observations are required to fully evaluate the full effects of treatments imposed on a biological system such as a seedling. Long term monitoring and observation require commitment, not only in terms of time by interested individuals, but also, money. Financial support is crucial for continuous measurement, analysis of results and reporting of results for development and application. What makes meetings like this important for advancement of our forest management practices is inter-disciplinary input or cross fertilization amongst scientific disciplines and between research and operations. Communication is the key to the successful transfer of science into practice.

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[1] Written text paraphased from notes by Dr. Keith M. McClain.

On a slightly tangential track, I would say that we need to begin measuring volume growth. Volume growth is the cumulative result of site factors and would serve in providing a better basis for economic analysis of our efforts and to justify intensive management techniques e.g. forest genetics (improved seed) stock, handling, vegetation management, etc. Of course, this brings us back to the reason why we are here. Physiological condition of seedlings is crucial for success in our plantations. However, what is our perception of a seedling? By what has occurred here in this meeting I am convinced that the majority of us are convinced that seedlings are complex organisms that respond to stress; the nature of the stress coupled with the vitality of the seedling mediate the form of the response. "Stress", as we use it, refers to actions or conditions that influence seedlings. Before we can predict response we must know in detail, what we are dealing with before we can understand how to manage it to achieve our objectives.

12.0 POST MEETING OBSERVATIONS

A.J. Willcocks, Manager
Northwestern Ontario Forest
Technology Development Unit

Some time has passed since our first meeting Aspects of Planting: Biology of Practice was held and it seems only appropriate that I comment on what I perceived happened and what has evolved as a result of the meeting.

Much of where we are now in our understanding of planting and those factors that contribute to the level of success achieved is owed to many past and current research efforts. Dr. Roy Sutton provided the keynote address in which he skillfully summarized, from a historical perspective, the progression of our understanding of stock quality and factors of handling that affect plantation success.

To further acquaint the workshop participants with the complexities of stock handling from a physiological standpoint Dr. Denis Lavender outlined basic seedling biology and its relationship to stock handling. This was followed by a discussion of stock handling techniques used in both nurseries and the field.

With a wide array of speakers from industry, government, and the scientific community in attendance, many stock handling ideas (tips) and new knowledge were conveyed to all attendees. This transfer of information occurred during and after the various sessions, but was especially apparent in the Wednesday evening session in which open group and one on one discussions were encouraged and have continued in our daily work.

On the final day, a special talk on "Area Based Planting" was given by Dave Lehane of British Columbia Forest Products. This new form of planting administration is likely to be tried and evaluated in Ontario for the 1989 season.

From this workshop, a number initiatives have begun:

a) Seedling Stock Handling Guidelines for Northwestern Ontario will be completed by the TDU - ready for the 1989 field season.

b) Area Based Planting trials will be initiated in 1989.

More important than the formalized initiatives were the contacts made by both speakers and field personnel and the little "tidbits" of knowledge that were exchanged amongst participants. I believe that the accomplishments of this workshop will variably contribute to the improvement of field stock handling because of the increased awareness by reforestation workers of the impacts various handling practices have on plantation success.

EVENING PRESENTATION

SHOOT AND ROOT GROWTH RESPONSE OF BLACK SPRUCE CONTAINER STOCK SUBJECTED TO FIVE OVERWINTERING TREATMENTS

E.R. Frisby and R.J. Day
Undergraduate Student and Professor, School of Forestry,
Lakehead University, Thunder Bay, Ontario.

ABSTRACT

Late crop black spruce (Picea mariana (Mill.) B.S.P.) container stock grown under the double cropping system with extended greenhouse culture were subjected to five overwintering treatments: 1) Exposed, 2) Snow Covered, 3) Styro-Pellet Covered, 4) Styrofoam Cap Covered (all in the outside holding area), and 5) Cold-Stored at -3 °C (in the refrigerator) during the winter of 1987-88. The stock was sampled in December, January and February and immediately potted for 21-day tests in controlled environment chambers to assess both shoot and root growth potential after each sampling time. The ability of the stock to flush shoot buds and to elongate roots was significantly reduced in the 'Exposed' (1) and 'Styro-Pellet Covered' (3) treatments in January (after 42 days in the outside holding area). It was greatly reduced by February (after 84 days in the holding area). Snow, Styrofoam caps and placement in cold storage at -3° C maintained the stock's ability to flush buds and significantly increased its ability to elongate roots from December to February. Increase in flushing time from December to February suggested that late crop stock subjected to extended greenhouse culture had not become fully dormant [i.e. unable to flush] by February.

AN EXAMPLE OF NURSERY CULTURAL CONTROL OF SEEDLING FIELD PERFORMANCE

K.D. Odlum and S.J. Colombo
Ontario Tree Improvement and Forest Biomass Institute
Ministry of Natural Resources
Maple, Ontario

ABSTRACT

In the summer/fall of 1986, operationally grown black spruce seedlings were exposed to one of three short daylength or two natural daylength bud initiation regimes as a means of terminating shoot growth in preparation for overwintering. In the spring of 1988, after overwintering outside, seedlings from the five regimes were planted at the Midhurst Research Station of OTIFBI where they were monitored weekly for second-year bud flushing, shoot elongation and bud initiation.

Second year shoot growth following planting was measured weekly until shoot growth had ceased, and the proportion of seedlings actively growing at each weekly interval was calculated. After July 3, there were always more short day seedlings active in the plantation than there were natural daylength seedlings. After August 1, almost 10% of the seedlings that had short daylengths applied the previous year were still actively growing, while none of the seedlings from natural daylength regimes exhibited any signs of shoot activity. It follows that short day seedlings which continued shoot growth late in the summer would be at greater risk of being damaged by early fall frosts.

Second year bud initiation of the short day treated seedlings occurred 3 to 6 weeks later than for the natural daylength seedlings, as determined by examining weekly samples of shoot tips under a dissecting microscope for the presence of newly differentiated budscales.

Earlier bud flushing and later bud initiation of the short day treated seedlings resulted in greater total second year shoot elongation.

The growth increment for the seedlings from short daylengths was 12.3 cm as compared with 10.3 cm for the seedlings from natural daylength regimes.

The physiological mechanism by which a two week exposure to short daylength in the first year can have such a dramatic affect on the timing and duration of shoot growth in the second year is not yet known. However, the benefits of increased growth observed in short day treated seedlings must be weighed against the increased risk from damaging frosts, in the spring and in the fall, during the first after planting.